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ABSTRACT

This book describes methods used in the education of science teachers. Chapters in the book and authors are as follows: (1) "Teaching Elementary Teachers How to Use the Learning Cycle for Guided Instruction in Science" (John Staver and Gail Shroyer); (2) "Helping Preservice Teachers Master Authentic Assessment for the Learning Cycle Model" (Nancy Murphy) (3) "Teaching Science 'Backwards': Changing a Preservice Teachers' Conceptions about Planning Using a Learning Cycle Model" (Suzanne Weber); (4) "The Process of Planning for Science Learning" (James Lubbers); (5) "Helping Teachers Integrate Science Across the Curriculum Using the Learning Cycle" (Ann Cavallo and Larry Schafer); (6) "Integrating Science into the Curriculum Through Narrative" (Michael Jaeger and Carol Lauritzen); (7) "Introducing Elementary Teachers to Thematic Science Instruction" (Patricia Keig); (8) "Helping Science Teachers Develop Effective Classroom Groups" (Nanette Eklund); (9) "Using the Learning Cycle to Introduce Cooperative Learning" (Alan Colburn); (10) "Constructing Concepts of Constructivism with Elementary Teachers" (John Staver); (11) "Eliciting Preservice Elementary Teachers' Beliefs About Science Teaching and Learning" (Sheila Jasalavich and Larry Schafer); (12) "Helping Middle School Pre-Service Teachers to Address Students' Alternative Conceptions" (Saouma BouJaoude); (13) "Increasing Student Curiosity, Persistence, and Critical Thinking During Science Activities" (John Bath); (14) "Having Elementary Preservice Teachers Experience Science as a Way of

Knowing" (Paul Jablon); (15) "An Analogical Technique for Teaching Question-Asking Skills to Science Teachers" (Roger Norris); (16) "Teaching Teachers to Use Operational Questions" (Frank Misiti, Jr.); (17) "Authentic Dialogue" (Michael Kamen); (18) "A Performance Based Approach to Preparing Elementary Science Teachers" (Thom Votaw); (19) "The Science Act: ity Filter: Guidelines for Improving the Selection of Scier.ce Activities" (Peter Rillero, Erica Brownstein, and Betsy Feldkamp-Kemp); (20) "Educating Science Teachers Through Action Research" (Dale Merkle); and (21) "A Celebration of Learning" (Ronald Bonnstetter). (PR)

BEHIND THE METHODS CLASS DOOR

EDUCATING ELEMENTARY AND MIDDLE SCHOOL SCIENCE TEACHERS

Editor: Larry E. Schafer

1994

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ERIC

Behind the Methods Class Door

Educating Elementary and Middle School Science Teachers

AETS Yearbook

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Preface

Corner a colleague and boldly ask, "What goes on behind your methods class door? What methods do you use to teach your students about science teaching and learning?" Be prepared, however, for the artful dodge which comes in many forms — program descriptions, activities for teaching science concepts or skills, a listing of the methods course topics, a defence of priorities, curriculum reforms, and so on. While these "dodges" are extremely important issues, they do not always describe the "how" or techniques of methods instruction.

For reasons best left unexamined here, we science educators tend to be somewhat apprehensive about not only describing what we do in our methods courses but asking others to do likewise. We want to know but are afraid to ask or reveal. The task for this Yearbook was to boldly ask, block the dodge, and crack open some methods class doors. The authors who described their methods of methods teaching in this book have courageously allowed us a look into their classrooms. What we see through their classroom doors are answers to questions such as:

How do you teach your students to design and authentically assess learning cycle instruction?

What techniques do you use to teach about thematic instruction and the integration of science and non-science subjects?

What methods and materials do you use to teach about classroom management and cooperative learning?

How do you creatively teach about constructivism and associated educational practices?

What do you do or have your students do which improves their attitudes toward science, scientific investigations, and science teaching?

How do you teach your students to effectively ask questions, initiate and sustain authentic dialogue, select appropriate science activities, and create and recreate portfolios?

Eleanor Duckworth, in a classic article, "The Having of Wonderful Ideas," describes how her extensive study in Geneva with Piaget had not prepared her for creative curriculum development. The theory she was most familiar with was not automatically translated into effective practice. Teachers and educators who were goal directed, but not working from formalized theory, were able to create science instruction which excited children and engaged them in "the having of wonderful

ideas." In other words, Duckworth reminded us that development need not always progress from theory into practice, but can and often does progress from practice into theory. This yearbook has been an attempt to find the bits and pieces of practical pedagogy (practices, if you will) which might find direct implementation in methods classes, which might stimulate new ideas for practice, and which might inform theories of science teacher education.

One of the objectives of this Yearbook was to encourage a large number of professors from a broad array of colleges and universities to describe their methods of teacher education. To that end, the science education community at large was invited to submit proposals. Papers were solicited from individuals whose proposals focussed on methods of teacher education. The papers were assessed and recommendations for revisions were made. A revised set of papers were then "blindly" reviewed by panel of science educators (see acknowledgements). Each paper was reviewed by three people. Obviously, reviewers did not review their own papers. Comments from the reviewers and editor served to guide revisions of selected papers. The final set of papers was chosen by the editor for inclusion in the Yearbook.

Acknowledgements

Many science educators have contributed their time, effort, and insight to the development of this Yearbook. I wish to thank Bill Ritz for providing invaluable assistance during the creation and design of this project. Without Bill's encouragement, inspiration, and ideas, this Yearbook would not have been completed. I wish to thank the authors who courageously offered glimpses into their classrooms and who persisted through the many rounds of feedback and revision.

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Teaching Elementary Teachers How to Use the Learning Cycle for Guided Inquiry Instruction in Science

John R. Staver and M. Gail Shroyer

One way for elementary, middle, and high school teachers to exemplify the current reform in science education is to teach science via the Learning Cycle (e.g. Lawson, Abraham, & Renner, 1989). Effective use of the Learning Cycle offers teachers continuing opportunities to recognize students' prior knowledge and alternative conceptions, and to provide learning experiences which help students to revise alternative notions as well as to develop entirely new concepts through a constructivist-based instructional model.

Purpose

One of our goals as elementary science methods instructors is to teach students how to use the Learning Cycle. Our purpose in this article is to describe how we introduce elementary science methods students to the Learning Cycle as a teaching model. The principle that we follow is first to model the teaching we want students to eventually carry out, and then describe the characteristics of the teaching which we have modeled. Because the Learning Cycle is a guided inquiry model based on constructivist principles, we introduce students to the Learning Cycle through a series of guided inquiry activities that constitute several Learning Cycles. In short, our students first experience the Learning Cycle in action prior to a formal introduction of its rationale and structure.

In addition to achieving our primary purpose, this experience enhances students' understanding of the science concepts that form the context for introducing the Learning Cycle. Through the activities described below, we take the students through three Learning Cycles as they experience phenomena of electricity, invent definitions of closed and open circuits, apply these concepts, invent definitions of series and parallel circuits, and discuss applications for such circuits. The origins of the activities are undoubtedly in the Batteries and Bulbs unit of the post-Sputnik curriculum *Elementary Science Study* (Educational Development Center, 1966). Current versions of *Elementary Science Study* units are now published by Delta Education.

We utilize the five-stage version of the Learning Cycle - Engage, Explore, Explain, Elaborate, and Evaluate - which was developed by BSCS for its new elementary (BSCS, 1992) and middle school (BSCS, 1994 a,b,c) science curricula. The BSCS staff refer to this version as the Instructional Model. The

original Learning Cycle, developed by Robert Karplus and his colleagues for *Science Curriculum Improvement Study*, SCIS, consists of three stages, Exploration, Invention, and Discovery. Karplus and his co-workers (1977) renamed the three stages as Exploration, Concept Invention, and Concept Application for *Science Teaching and Development of Reasoning*, a set of workshop materials developed for improving high school science instruction. The stages in the Karplus models correspond to the middle three segments of the BSCS Instructional Model. The first and last stages in the BSCS Instructional Model, Engage and Evaluate, were added to the Karplus models to make a more complete cycle. The Engage stage is used to capture students' attention and determine their understanding prior to beginning instruction; the Evaluate stage is used to assess what students have learned following instruction.

The Learning Cycle in Action

Engage

Setting the stage, we tell students in this segment of the course that they will learn how to design and carry out guided inquiry science lessons according to a specific teaching model. Moreover, they will use this model to teach their lessons in class and then in their field experience sites. We tell students that we will introduce them to the teaching model by modeling it, with us as teachers and them as students.

We begin by asking the question, "What is the most difficult, least understandable area of science for you?" Responses vary, but students often name, "Physics!" We continue by asking, "What is the most difficult part of physics?" Again, a frequent response is, "Electricity!" We then dangle the bait with a challenge, "So you believe that electricity is perhaps very difficult to understand. If we can show you how you can understand electricity in a meaningful way and also teach electricity to elementary school youngsters in a meaningful way, then would you believe that you can understand and teach almost any concept in science, because almost everything else must surely be easier to understand and teach than electricity?" Again responses vary. A few students agree; most remain noncommittal. More important, we have captured their attention, and learned a great deal about their prior knowledge in science and science education, two important purposes of the Engage phase of the Learning Cycle.

Explore

Beginning this phase, we direct students to work in two- or three-person teams with a goal of arranging a D-cell, a flash light bulb, and a length of wire so the bulb lights. We distribute a D-cell, a flash light bulb with one end of a 30cm length of copper wire wrapped around its base, and several small squares of blank paper to each team. Students must draw a diagram of each arrangement tried on a separate piece of paper and label it 'yes' or 'no' as to whether or not the

arrangement lights the bulb. To get them started, we often hold up the D-cell, bulb, and wire so that the D-cell does not touch the bulb or wire and ask, "Does this arrangement light the light? Here is one that you can draw and mark 'no'." Students spend 15 minutes trying various arrangements. We move about the room, asking questions, offering advise, and giving suggestions but few, if any, answers.

When students have exhausted their ideas for arranging and testing the D-cell, wire, and bulb, we ask for their attention and give the following direction, "One person from each team should put all the drawings marked 'yes' on the table marked 'yes.' Another member of each team should place all drawings marked 'no' on the table marked 'no'." Students then go to the tables, inspect the drawings, and identify common elements among the arrangements that light the bulb or fail to do so. They spend about 10 minutes examining the drawings, searching for patterns in the data, testing questionable arrangements with their own materials, and discussing their ideas about why some arrangements light the bulb, whereas others do not. This concludes the Explore phase.

Explain

Beginning the Explain phase, we involve students in an interactive question-answer session which focuses on identifying common elements of specific arrangements which light or fail to light the bulb. Asking a series of questions, we direct them to construct a description of an arrangement which lights the bulb and to use only vocabulary that a second or third grader would typically use in a description. Two students act as vocabulary referees, judging the sophistication of the words used in the description. We write their description on the chalk board as they develop it. There is always a great deal of discussion among the students, and the referees sometimes throw out complicated words. Consequently, there is considerable modification of the description as it is developed on the chalk board. An example of a completed description is: "One end of the wire touches one end of the battery. The other end of the wire touches the yellow base of the bulb. The silver tip on the base of the bulb touches the other end of the battery."

Students agree that this is a description of an arrangement that will light the bulb. We then challenge them to develop a conceptual description based on their specific description of how the items are arranged. Students usually struggle with this task, and to get them started we ask, "What does the wire represent?" Responses vary, but someone usually says that the wire is a route or a path. We wait specifically for someone to mention the word 'path.' We then ask students to modify their first description so as to include the concept of a path. Again, students alter the original description through discussion, and we write the new description on the chalk board as they develop it, being careful not to erase the original description. An example of the revised description follows: "There must be a path around the battery from one end to the other end of the battery. The bulb must be in the path."

When we are sat· .ted with the description, we label it as a closed circuit, and we discuss the cr .cept. We then ask students to explain why the arrangements on the ' -' .ole fail to light the bulb. They usually point out very quickly that the path around the battery is broken or not complete. We immediately write this idea on the board and label it as an open circuit. Then we discuss their definition of an open circuit as a modification of their definition of a closed circuit.

Our experiences with preservice elementary teachers have clearly demonstrated that, although they now understand a closed circuit as a complete, unbroken path around a battery and an open circuit as an incomplete, broken path around a battery, they have little or no notion as to how the bulb is part of the path. Thus, our next question is, "How is the bulb part of the path?" Usually no one knows, so we suggest that they find out by examining the close, much larger relative of their small bulb, a 40-watt light bulb. We then distribute a 40-watt bulb and a hand magnifier to each team. The glass of each 40-watt bulb is already broken so the insides of the bulbs can be easily viewed. We direct students to inspect the wires and to find out where the wires go as they disappear inside the base of the bulb. More discussion follows, and students point out that one wire touches the metal base of the bulb, whereas the other wire attaches to the metal tip at the bottom of the bulb. The two wires are connected above the base by a very thin wire. We sketch a drawing of a bulb on the chalk board. If the students do not identify the thin wire as the filament, then we do so. Students use hand magnifiers to verify that their small bulb is built like the larger one. At this point, students are able to point out the path of wires through the bulb and to explain why the metal base and tip of the bulb are part of the path. This concludes the Explain phase. Perhaps 45 minutes have elapsed since this phase began.

Thus far, we have focused on introducing closed and open circuits as we, or they, may do in an elementary classroom. At this point, we redirect the focus toward the Learning Cycle as an instructional model by asking, "Why did we use the past 60 or so minutes to introduce closed and open circuits when we simply could have directed you to read the definitions of closed and open circuit in a science textbook? Reading the definitions and then discussing them might take perhaps 10 - 15 minutes. Why did we spend all the extra time?" Students usually point out the need to utilize hands-on science activities to introduce processes and concepts to elementary school students. They frequently mention Piaget's theory and point out how much more interesting hands-on instruction is for youngsters. We ask, "If the meaning of closed and open circuits did not come from a textbook, then where did the meaning come from?" In the discussion that follows, the students acknowledge and reflect that they constructed the meaning through their activities and discussions. At this point they often express an awareness that we, as teachers, were guiding them toward that end, but they did not realize it during the lesson. We always point out that we only supplied the terms 'closed circuit' and 'open circuit.'

Our next series of questions focuses students' attention specifically on their role as students and our role as teachers during the Explore and Explain stages of

the Learning Cycle. We ask, "What did we as teachers do during the light-the-bulb activity? Also, what did we not do?" Students typically point out that we asked a lot of questions and listened to them. Also, we encouraged them to keep thinking, try new alternatives, and talk to one another. They note that we did not answer their questions, give definitions, or put words into their mouths. Then we ask, "What did you as students do? What did you not do?" Students respond that they talked, explored, asked each other lots of questions, laughed, and struggled. Also, they point out that they sometimes became frustrated and embarrassed when they could not light the bulb, and then became excited when they were successful. Students tell us that they did not receive much information from us and did not listen to lectures, memorize definitions, or read boring books. We then repeat these questions, asking students to focus on teacher and student roles beginning with the inspection of the drawings (start of the Explain phase) and ending with the introduction of the terms 'open circuit' and 'closed circuit (end of the Explain phase).' Regarding teacher roles, students point out that we encouraged them to explain ideas in their own words. Also we continuously referred to actions and data, not abstract concepts, in asking our questions. Regarding student roles, students respond that they d: cribed and explained their ideas to each other and to us, used the activities to de . elop explanations, and did a lot of difficult thinking and reflecting.

Emerging from this discussion are students' descriptions of teacher and student roles for the Explore and Explain stages. At this point we introduce the term 'Explore' in terms of student and teacher roles during initial light-the-light activity, then define it as experiences which provide a foundation for developing students' comprehension of a concept. Then we introduce the term 'Explain' in terms of student and teacher roles and define it as the stage following Explore in which the teacher clarifies the concept and introduces vocabulary terms associated with the meaning of the concept.

At this point, we return to our initial question about electricity being such a difficult idea to understand. We often ask, "Have you learned anything new about electricity?" Many students respond that they did not understand circuits or how light bulbs work until now. Next we ask, "What did you think about our challenge that if you could understand and teach electricity, then you could understand and teach almost anyth'ng in science?" Students often reply that they thought we were joking, that there was absolutely no way that we, or anyone, could make electricity comprehensible. We then often ask, "OK, but did we get your attention?" Students usually reply that we did and frequently offer one of two reasons. They state that they were intrigued by the challenge regarding electricity or that they knew that they must design and carry out inquiry science lessons. At this point, we introduce the term 'Engage' for first stage of the Learning Cycle, define it as an event or question related to the concept that the teacher plans to introduce. Next, we review and discuss the Engage, Explore, and Explain stages in terms of their sequence, the questions and activities done thus far, and the appropriate as well as inappropriate teacher and student roles in each phase.

Finally, we introduce the term 'Learning Cycle' and define it as a five-stage instructional model. We point out that we have already modeled the first three stages. Two more stages remain to be modeled.

Elaborate

As a transition, we ask students to speculate as to what the nature of the yet-to-be-introduced stages could be. A good question is, "Thus far, we have captured your attention in Engage, provided you with a concrete, activity-based foundation for developing the concepts of closed and open circuits in Explore, and clarified the meaning and introduced the term for the concept in Explain. What other elements of high quality teaching and learning have we not yet done and could be carried out following Explain?" Students' most common response is the application of newly introduced concepts to familiar, everyday situations. At a more general level, students express a keen interest in using science to address and solve individual, communal, and societal problems. We capitalize on their comments and point out that teaching students how to apply knowledge to new problems, although often taken for granted, is a fundamental goal of science education. We emphasize that, if application of knowledge is an important goal, then as teachers we must teach specifically for application of knowledge. Moreover, we note that they have just described the next stage of the Learning Cycle, and we introduce the name Elaborate, identify it as the stage following Explain, and define it as a set of experiences for building students' understanding of concepts by applying the concepts to new situations.

At this point, we refocus students' attention on the application of closed and open circuits, saying, "As we proceed through the next activity, reflect not only on the application of circuits, but also on the characteristics of this activity in terms of its place in the Learning Cycle." We distribute a file folder to each team. The folders have six metal notebook brads (labeled A,B,C,D,E,F respectively) sticking out as shown in Figure 1. The folders are taped shut so that they cannot be opened easily. We tell the students, "The metal brads *may be* connected by wires in some manner inside the folders. Work in your team to test for connections with your D-cell, bulb, and copper wire. Record your data for each possible connection on a piece of paper. Develop a model of a circuit diagram based on your data and draw the diagram on a piece of paper." Students must use their newly constructed concepts of closed and open circuits to do this task. They typically spend about 10 - 15 minutes collecting data and developing a circuit diagram. We move about the room, again asking questions, offering advice, and giving suggestions but not answers.

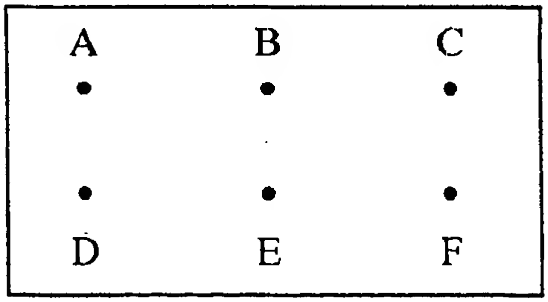

Figure 1. *Diagram of the outside of a file folder circuit board.*

When all groups have constructed a possible circuit diagram, we pick up two drawings of circuit diagrams which are different. Then we ask students to help us write a summary of their test data on the board. A typical summary is shown in Figure 2. Each connection is marked '+' or '-,' depending on whether or not it lights the bulb. We then draw the two collected circuit diagrams on the chalkboard and ask students for their thoughts and opinions. Students in other teams often point out that their own teams constructed diagrams identical to one of the two shown on the board. Sometimes a third alternative is presented. Students usually ask questions about which diagram is correct. If they do not ask, we ask them if they think that only one is correct. They often reply affirmatively. We then take students through an examination of the two circuit diagrams with respect to the data; they realize that both circuit diagrams are consistent with the data. At this juncture we point out an important characteristic of inference as a process skill, namely that the circuit diagrams are inferences from the data and that more than one inference may be consistent with data. If students have generated only two circuit diagrams, we then challenge them to identify twelve additional circuit diagrams which are consistent with this data. As students develop new diagrams, we draw them on the chalkboard. All circuit diagrams are presented in Figure 3. This activity requires perhaps 30 - 40 minutes.

At this point, we refocus on the Learning Cycle as a teaching model. Because we have already introduced the term 'Elaborate' and defined it, we center again on student and teacher roles. The students generate lists of appropriate and inappropriate teacher and student roles. These roles are then discussed extensively. This concludes the 'Elaborate' phase.

AB	+	BC	+	CD	-	DE	-	EF	-
AC	+	BD	-	CE	+	DF	-		
AD	-	BE	+	CF	-				
AE	+	BF	-						
AF	-								

Figure 2. *A summary of student data on their examination of potential connections inside the file folders.*

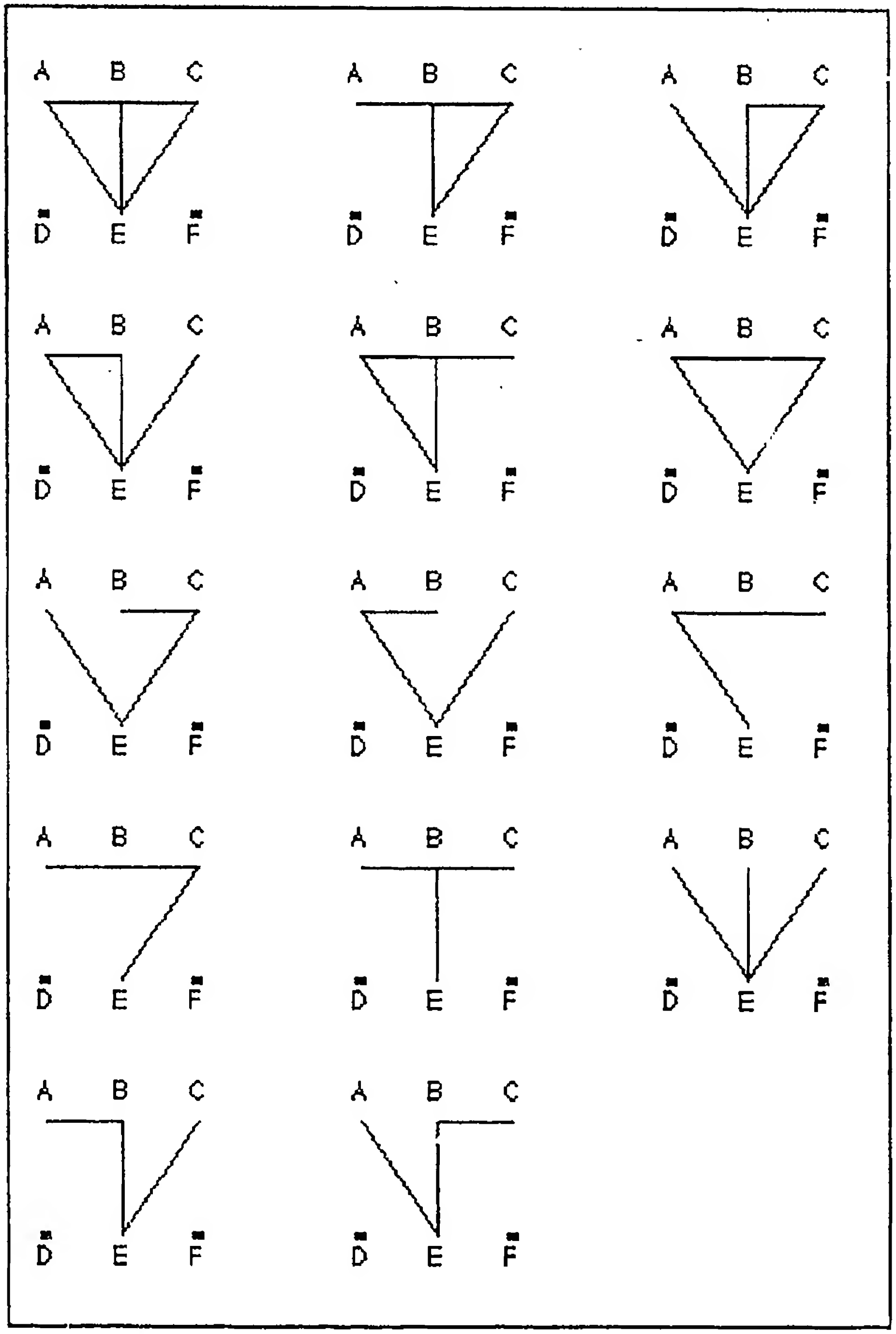

Figure 3. **Circuit diagrams which are consistent with the data in Figure 2.**

Evaluate

If students have not yet mentioned evaluation in their speculations above, we ask, "What else should a teacher do at this point?" Usually someone will respond that the teacher needs to find out what students have learned. If not, we typically ask, "If you were us, what would you do to assess how well your fellow students understand circuits?" Responses vary, but students typically mention paper-and-pencil tests. An extensive discussion then occurs regarding paper and pencil tests. We ask questions such as, "What can you assess with paper-and-pencil tests? Could you do well on a paper-and-pencil test and still not understand the concepts? Could you understand the concepts and not do well on a paper-and-pencil test? What else could you do that might be a more authentic assessment?" Many issues are discussed, including learning styles, matching goals with instruction and evaluation, and the need for authentic assessment. Based on our experiences with these discussions, it seems clear to us that doing hands-on activities as a means of evaluation is a novel concept for students.

We then introduce the term 'Evaluate', describe it in terms of the activities that we are discussing, and define it as the final stage in the Learning Cycle in which students do activities that help the teacher to examine their students' understanding of the concept. Next we ask students to generate a list of possible assessment strategies that represent a multifaceted evaluation. An extensive variety of activities is generated and examined in the ensuing discussion. These activities emphasize writing, speaking, doing, attending to different learning styles, and provide avenues for triangulation of their results.

Our evaluation of students' comprehension of the Learning Cycle focuses on our primary goal, to enhance students' understanding of the Learning Cycle model and their ability to design and carry out Learning Cycle instruction. However, introducing the Learning Cycle by modeling it has afforded us ample opportunities to examine their understanding of closed and open circuits. The extensive interaction and student talk has allowed us to listen while the students tell each other and us what they know about circuits during the Engage, Explore, Explain, and Elaborate stages. Moreover, we have also made several informal assessments regarding their knowledge of the Learning Cycle. We ask students to describe what they have learned about circuits and about the Learning Cycle by writing in their journals, which are an on-going part of the course.

At this point, we turn our attention to designing and teaching Learning Cycle lessons in partial fulfillment of their field experience associated with the science methods course. Students carry out the assignment in phases, with their work in each phase being evaluated. First, they must choose and obtain approval of a science concept appropriate to the grade level of their field experience students. Then, they design the instruction itself according to the five-stage Learning Cycle. This segment includes preparation of lesson plans and materials lists. Next, students peer teach their lessons in the methods class. Peer teaching sessions are video taped and followed immediately by self critiques and suggestions from us and from fellow students. Finally, students revise and teach these

lessons in field experience classrooms in local schools. The lessons are evaluated by the classroom teacher whose students experience the lessons, by us, and by the methods students themselves. Thus, the assessment is an authentic one.

Cycling On...

At this point, the students have experienced one complete Learning Cycle. Our modeling of the Learning Cycle continues, but now we ask students to think specifically about a teacher's role as they do the activities that follow. For example, we say, "As you do the following activities, think about them in terms of the stages of the Learning Cycle and in terms of a teacher's role. Identify what you do during the Engage, Explore, Explain, Elaborate, or Evaluate phases."

We then distribute a second bulb, a second D-cell, two bulb holders, and three additional pieces of copper wire. We direct students to tape the two D-cells together end-to-end, unwrap the first copper wire from its bulb, put the bulbs into the bulb holders, and construct an arrangement so as to light both bulbs at the same time. Almost immediately, students identify this as an Elaborate activity. Working with individual groups as they create a successful arrangement, we ask students to take one light out of the circuit. Most groups build a series circuit, so the second light ceases to shine when the first bulb is removed. We ask, "How many paths are present in this circuit?" Students usually answer, "One." Our next question is, "Would you please trace the path with your finger?" They usually respond quickly and successfully. Then we ask, "Why does the second light go out when you remove the first light from the circuit?" The typical answer is that the path is broken when the first bulb is removed from its holder. Next we ask for a description of this arrangement. A typical answer is: "There is only one path around the battery; both bulbs are in the path." If no one has already volunteered the name, we then introduce the term 'series circuit' to describe this arrangement and ask, "Having finished the activity, what stages of the Learning Cycle best describe it?" Many students reconsider their earlier choice and now identify it as an Explore and Explain activity. In the following discussion, we point out how Elaborate as a stage can quickly become Explore followed by Explain.

In a final activity, we direct the group to develop an arrangement such that, when one bulb is removed, the other bulb continues to shine. By now students often say, "What are you going to introduce now? Here comes another Explore." Our response to such a question is, "Try to anticipate. Tell us what your ideas are before we actually introduce the term." We move about the room offering assistance and advice as the groups work. Students quite often struggle with this task. Sometimes groups set up two separate circuits, each with a single light in its own path. When this occurs, we direct them to try an arrangement in which only two wires touch the batteries. When one or two groups achieve success, we have their members demonstrate their arrangements to the others. In doing so, a student removes one bulb from its holder and traces the path of the electricity for the second bulb. The student then replaces the first bulb, removes the second bulb, and traces the path of the electricity again. Other groups then build an

arrangement like the one just demonstrated. When each group has built and tested its arrangement, we ask, "How is the path of this circuit different from the series circuit that you built earlier?" Students typically point out that the other bulb continues to shine because, although some wires are shared, each bulb has its own path. We then ask if anyone knows the name of this kind of circuit. Sometimes students tell us that this is a parallel circuit. If they don't, then we introduce the term 'parallel circuit' and define it according to the students' descriptions.

In the discussions that accompany and follow these activities, students mention several applications of series and parallel circuits. A frequent example is a string of Christmas tree lights as a parallel circuit. We point out that we are old enough to remember Christmas tree lights in series. We tell students about the instance in which the first author's father became so frustrated in trying to find the bad bulbs in a string of series Christmas tree lights that he tossed the lights into the trash.

A Concluding Reflection

We judge much of our success as teachers in terms of our students' achievement. Our extensive experiences with elementary science methods students have taught us that a primary element in our students' eventual success in designing and carrying out Learning Cycle instruction, and consequently our own success as teachers, is our willingness to model the teaching that we want our students to implement. We think of this as honoring the principles of constructivism upon which the Learning Cycle is founded.

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Helping Preservice Teachers Master Authentic Assessment for the Learning Cycle Model

Nancy Murphy

Educators are creating a revolution in assessment by insisting that assessments document the ability of students to act on information, not simply their ability to recall information. This revolution is calling for reform of standardized and instructional practices in assessment. This paper addresses only one small component of evaluation and assessment: those practices that occur in the process of instruction that inform the teacher of the students' current knowledge and schema of the topic at hand. I review the purposes of assessment, many tools that can aid teachers to easily document the current understandings and skills of their students, and some methods course strategies that have helped preservice teachers apply these assessment practices in their first practicum experience. The strategies are designed to simplify assessment and decrease the amount of paperwork required of teachers while increasing their intimate knowledge of what goes on inside the heads of each of their students. I also describe how I help preservice teachers acquire these skills. My preservice teachers typically use a Learning Cycle Model for their lesson designs. Consequently, strategies for authentic assessment are presented within the context of this Learning Cycle Model.

Purposes of Assessment

Traditionally, assessment referred to the documentation produced which provided feedback to students, administrators and parents on performance, both normative (how individual students compare to each other) and criterion-referenced (how they performed related to the goals and expectations of the course). Assessment typically occurred after instruction and was a separate component of the educational process. You might have noticed that I left "teachers" out of the audience ascribed to traditional assessment practices. I justify that omission because, relatively speaking, teachers usually already know how their students perform in relation to each other and their criteria. The tests simply document this teacher knowledge for others.

Several developments make the traditional form of assessment limiting for modern teachers.

1. The demands to prepare students with options to pursue either a scientific profession, scientific political effectiveness, or public scientific literacy

require more effective use of limited class time. Traditional assessment techniques require development time that competes with the instructional demands placed upon teachers, and the results are rarely used in a formative manner.

2. "Our present-day Western European society is geared to developing self-motivating individuals with high-esteem who can cope with an unknown future characterized by a deluge of new information" (Davis; 1980). Teachers are beginning to shift from expectations of prescribed, predicted, and coerced outcomes towards indicators of adaptive, creative, and effective behaviors in their students. Traditional assessment practices often look only for indication that the students have acquired prescribed information.
3. Educators are increasingly accepting a constructivist learning philosophy. For the purposes of this article, I will define contructivism simply as the belief that students actively construct their personal understandings (images or schema) by modifying their prior schema rather than receiving knowledge intact from an instructor. Every student enters an experience with a unique schema, and instruction must provide multiple entry points so that all students can engage and modify their current schema if necessary. Teachers must actively elicit students' schema and invite students to act upon them. Traditional assessment strategies do not provide this ongoing information during the process of instruction.

Therefore, effective instruction requires that teachers acquire immediate information on students' understandings in order to continuously modify and manage the learning environment.

What is Authentic Assessment?

With that requirement in mind (acquiring immediate information on students' understandings), I am restricting my definition of authentic assessment in this paper to "assessment in service to instruction". Therefore, authentic assessment is the determination and documentation of students' current understandings so that teachers might better address students' immediate needs. It could be considered a form of micro-assessment since it is continuous and formative. However, with proper documentation, authentic assessment practices can result in the collection of a portfolio of documents which can then be used for normative or criterion-reference purposes.

Authentic assessment is sometimes referred to as "nested assessment". It should be distinguished from the broader definitions of alternative assessment (roughly anything other than a multiple-choice or standardized test) and performance assessment (assessment that requires students to perform an activity, usually applying several combinations of process skills or problem solving strategies). It should also be distinguished from other definitions of authentic assessment (which some people refer to as assessing any skill that is used

authentically within a profession) primarily by the distinction that it should occur within the actual instructional activities, not as a separate activity.

A Brief Definition of Learning Cycle Model (LCM)

This article presents the authentic assessment strategies within the context of the learning cycle model. Although the literature contains numerous variations, a learning cycle model approach generally contains five stages. It begins with an initial engagement phase which activates student interest and elucidates students' prior knowledge or schema for the concept. This is followed by an exploratory phase in which the student interacts with the objects to gain an intuitive sense of the phenomenon in question. The third phase usually includes guided discoveries during which the students "invent or discover concepts" that give meaning to the experiences of the exploratory phase. It may also include a separate phase of experimentation, during which students use complex process skills to create and validate new knowledge. Finally, the students apply their newly learned concepts and skills in additional contexts to practice them and to extend the range of their usefulness (Gallagher, 1979; Murphy, 1989). The result is a somewhat flexible sequence including engage, explore, discover, experiment, and extend. The learning cycle model is widely used and accepted as an effective instructional model in science education.

The learning cycle model is also a valuable sequence for exploring unfamiliar phenomena along with your students. In situations where the teacher knows nothing of the accepted knowledge about a phenomenon, both the teacher and the students focus upon the application of process skills, collaborative social behaviors, and critical thinking to collectively construct shared understandings.

Authentic Assessment Within the Learning Cycle Model

The learning cycle model approach demands that teachers engage in continuous informal assessment of student understandings. Table 1 provides an insight into the nature of those assessments.

Authentic Assessment Tools

Brief descriptions of these assessment tools are provided below. Most of the examples come from effective practices contributed by Alaskan teachers who are actively involved in the Alaska Science Consortium (a professional development effort guided by Alaskan teachers and funded in part by NSF, UAF, and member school districts).

Concept Webs

Concept webbing is a connected collection of words that represent one's understanding of the relationship between ideas. It is more analogous to a road

Table 1

Assessment considerations for the Learning Cycle Model

LCM Stage	Assessment Purpose The teacher wants to be able to:	Assessment Type
Engage	Determine each student's preconceptions in order to provide effective multiple entry points for exploration. If necessary, these can be documented (see list to the right) to serve as baseline information from which to assess growth. Facilitate engagement (as each student needs to find some way of activating his/her current schema in relation to the upcoming experiences).	Concept webs Prior knowledge charts Journal entries (fast-writes) Discrepant events
Explore	Document the students' use of elementary process skills of science. Recognize and improve the students' abilities to interact with peers and the phenomenon in a variety of modes.	Process skills checklists Journal entries Drawings Observation notes Center activity documentation Measurements and recording
Discover	Determine the degree of conceptual change in the students (students illustrate this by creating concrete and verbal models of their schema). Determine if more explorations are necessary. Identify student-generated testable questions for inquiry-based experiments. Reinforce behaviors that elicit and respect alternative explanations and ways of knowing.	Revisiting concept webs Draw pictures, create models Update "what we know, what we want to know, and what we found out" lists Interviews Journal entries
Experiment	Document the students' ability to use the complex process skills of refining testable questions, identifying and controlling variables, collecting, analyzing, and interpreting data, and drawing conclusions	Analytical trait scales Self assessments Procedure reports
Extend	Determine if the student can transfer the new understandings (either in a new context or in ways which benefit society). Facilitate new interests in students as they extend their original schema. (serves as "opener" instead of lesson "closure").	Creative drama, art and writing activities Career identification Inventions and science olympiad challenges Actual products which are of use to the student or his/her community
All stages	Document the students' thoughts and processes as they attend to relevant projects and activities.	Learning logs Group performance checklists LCM Analytical Trait Tools Portfolios and video portfolios Anecdotal records

map than to a dichotomous key. It is a piece of private thought made public for revision and review. Concept webs have the following advantages:

- They permit a variety of "right" answers to surface.
- They permit the comparison of student understanding to expert knowledge.
- They improve everyone's understanding as we search for personal meaning
- They illuminate preconceptions.

Ways to initiate concept webs:

- provide relevant terms and ask students to web their understanding of the relationships between those terms.
- have students help you to create a simple web on the board. Let them brainstorm terms and direct you with information on where to place those terms and why.

For example, a teacher might ask students to share all that they know about buoyancy. As the students begin to brainstorm about this subject they might make some of the following statements:

- "Some things float, some sink."
- "Light things float, heavy things sink."
- "I think if it's heavy it can float if you put it in a big boat."
- "Are we talking about things that float on air, too?"
- "Things float on top of the water, but they float in the middle of the air."
- "Some things float until the water gets over their edge and then they sink."

The teacher might prod more information from these statements by asking open-ended questions. The following phrases are useful tools for teachers:

- "Tell me more about what you mean by that statement."
- "Do you mean? If not, what do you mean?"
- "How do we explain the fact that we seem to be able to get some heavy things to float?"
- "Do we all agree that we don't quite know the relationship between floating on water and floating in air?"

During these discussions the following web (Figure 1) might be created on the board:

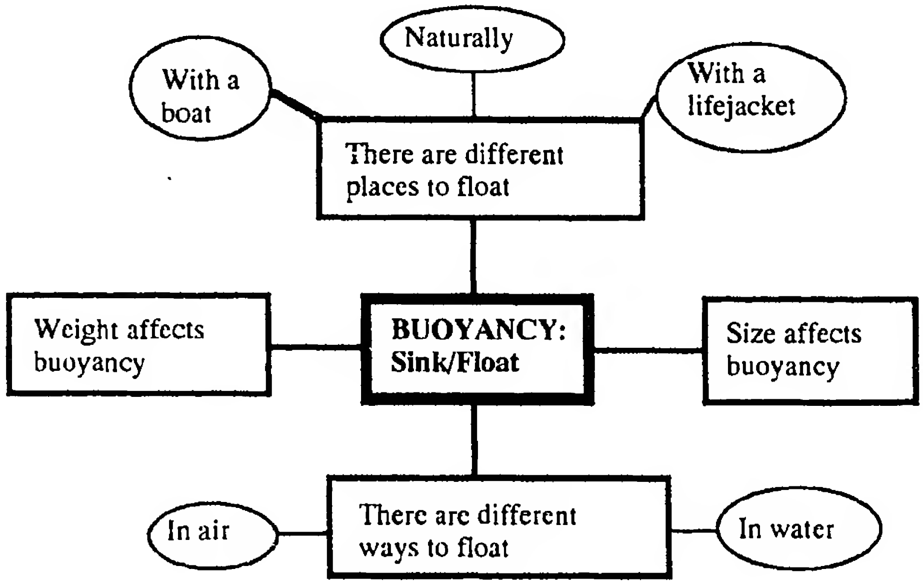

Figure 1. Student concept web regarding buoyancy.

From these discussions the teacher might infer that the students have had many experiences with buoyancy. They know that some things do float, some do sink, and they suspect that it has something to do with size and weight. They are not using the concepts of mass and density, but they have questions that can be answered with this knowledge. The students are also curious about the buoyancy issues in fluids such as air. Consequently, the teacher has a better idea of the range of educational experiences that will provide a comfortable entry point for these particular students.

I find that my preservice teachers need many experiences with concept webs before they recognize their value. I try to create sample concept webs with them every time that they begin to discuss science concepts. As they share their ideas for units to develop for their own instruction we stop and make a concept web of our understandings as teachers of those concepts. As they see how easily webs are constructed and how much informal information webs provide, they become more willing to use them informally in their own classrooms.

Prior Knowledge Charts

I encourage my preservice teachers to poll their students in the engagement phase on what they know and what they want to find out about the topic. After the lesson, they take a tally on what their students learned in the discovery phase.

Some people call these (Table 2) the What? (engage) That's what! (discover) and So what? (extend) charts.

Table 2
Prior Knowledge Chart

WHAT WE ALREADY KNOW:	WHAT WE WANT TO FIND OUT:
WHAT WE LEARNED:	

Discrepant Events

A discrepant event is generally a demonstration which presents a phenomenon that cannot be adequately explained by the student's current schema or level of understanding. For example, a teacher initiating a unit on buoyancy (sink/float) in a primary classroom might begin by asking the students to predict whether or not an orange will float; next they test their predictions with a hands-on activity. The teacher then peels the orange and repeats the predictions and tests. Now some students realize that making the orange lighter did not make it more buoyant as they predicted, thus providing a discrepancy for their current schema. As the students grapple with the ways in which they verbalize their schema on buoyancy, the teacher documents their preconceptions either as a concept web, a "what we know chart", or a simple list. If the students all predicted that making the orange lighter would make it float higher, they might make the following statements:

- "I guess heavier things don't always sink more than lighter ones."
- "It's like you took off its life jacket."
- "The inside is like a rock; the outside is like a balloon."
- "Can we call the skin the orange's boat?"

This information, along with information that was collected in earlier discussions (see my examples under the "concept webs" section), might lead to a "What we know" chart (Table 3).

Table 3
What we know chart

WHAT WE ALREADY KNOW:	WHAT WE WANT TO FIND OUT:
Some things sink; some float. Light things float better than heavier things. Some things float naturally. You can make sinking things float by putting them in a boat or a life jacket.	Do things float in the air the same way they float in the water? How are natural flotation, life jacket, and boat buoyancy alike/different?
WHAT WE LEARNED:	
Sinking and floating doesn't always depend upon weight. Some things that are heavier float better than things that are lighter. It might depend on the size and the weight.	

This information now allows teachers to provide experiences that directly address the readiness of their students. They might be prepared with a center in which they compare the mass of three objects that float (one naturally, one in a life jacket, and one in a boat-like piece of foil). They could design this center so that all of these objects are the same mass, thus encouraging the discovery that an object and its life jacket (or its boat) acts like one object. Further experiences will lead them to the discovery that both mass and relative density effect buoyancy.

Observation Notes

Observation notes (Table 4) are formatted to prompt elementary students to attend to more detail as they observe new phenomenon.

Center Responses

Many teachers create "worksheets" for students to use at centers. These guide the students through particular activities and aid them as they record their thoughts and results. The following example (Table 5) would be used at a center where differently colored salt water solutions of different densities are explored.

Draw Pictures, Create Models and Templates

The ability to identify and use models which portray or simplify scientific realities is one of the most complex tasks facing scientists. It represents the student's ability to combine the quantitative aspects of mathematics within the

reflection. The format looks like this:

(variable)	going up or down?
(variable)	going up or down?

In use the table looks like this:

age	child	adult	age: going up or down?	⇑
healing rate	high	lower	healing rate: going up or down?	⇓

The chart is effective because it permits the learner to set work out and record a few cases and then refer to the evidence in looking for the pattern.

A further extension of this study of trends permits students and teachers to investigate two-factor effects and analyze the relative influence of two separate conditions on a specified outcome. If, for example, we consider the "spaghetti spiciness" as the *outcome* that is of interest, then two contributing variables that could be considered are the amounts of garlic and oregano used in the sauce. For simplicity, and there are certainly more complex variations available, we'll consider only some ordinary set volume of spice in each case, and the options of "with garlic" or "without garlic," and "with oregano" or "without oregano." This leads us to four possible combinations, and students are asked to work out what those combinations are.

Up to this point the format looks like this:

- Outcome of interest: spiciness of the spaghetti sauce
- Variables: garlic and oregano
- Possibilities:

garlic +	garlic -	garlic -	garlic +
oregano -	oregano +	oregano -	oregano +

The next step is to place those possibilities in order from least spicy to most spicy, starting with the extreme cases.

- order:

garlic -	garlic +
oregano -	oregano +

This leaves the analytical task of determining which of the other factors is more influential in determining spiciness, since each of the other remaining, unused options includes one but not the other of the spices. When that determination is made, we can return to the line in the format in which the variables are listed

(garlic and oregano) and mark the one we have determined as more influential (under these conditions). In each case the range of normal values dictates the range over which we consider the variables, unless we specify another range. I recommend a gentle pace for this lesson segment so that time is allowed to discuss the importance of specifying the range, if appropriate.

We complete simple two factor sets to gain familiarity with the thought processes involved. Simple examples include:

1. An outcome of spelling grade in relationship to the difficulty of the words and to time spent studying,
2. An outcome of distance between footprints in relationship to the height of the runner and to the speed of the runner, and
3. An outcome of average annual temperature in relationship to latitude and altitude.

More difficult relationships occur where the content is less familiar, and where one of the relationships is direct and the other inverse.

In some cases these discussions lead to consideration of what is causal and what is simply coincident. Other extensions of the lesson involve graphing data from some of these relationships, and comparing trends that differ in slope, intercept, or range.

Preservice Teachers Plan Lessons with Trends

Preservice teachers take these experiences and apply them in lesson planning, and in teaching lessons in their field placements. Examples of trends can be found within the grade level curriculum in science throughout the school years. In one assignment the preservice teachers in my methods course read and respond to the school district curriculum guidelines for the location and grade level of their upcoming placement. One of their tasks within that assignment is to identify, within the recommended science content, variables that demonstrate a trend relationship. If desired, a grade level list of usable trends can be extracted from their papers.

When preservice teachers prepare lesson plans to teach about a trend, the pacing of lessons should be guided by consideration of students' familiarity with the concepts and variables involved. In many cases it will be appropriate to provide a hands-on investigation and perhaps the collection of data, before analyzing a trend.

Cycles

Lesson segments dealing with the teaching of cycles can also involve the pre-service teachers in higher-order thinking. Within cooperative groups, pre-service teachers are asked to develop a means of depicting cycles. For this lesson segment I have used both (a) salmon population through a few years at a particular stream

and (b) the speed of an automobile racer on an oval track through several laps. It would also be possible to ask each group to consider a different cycle, for example:

1. rainfall at a location for several years (observed by the month)
2. gerbil-minutes in the wire wheel over a week of observations (observed each hour)
3. depth of trash in the container in the lunchroom over a week
4. number of children on the school bus, over its route, repeated several days

The preservice teachers then explain these representations to their peers and draw their representations on the blackboard.

After sharing, groups are challenged to use another group's graphic form to show their own cycle in a different way. This use of cooperative groups also demonstrates its potential to slow students down, increase accuracy of interpretations, and encourage reflection, evaluation, and communication.

Among the most familiar cycles in the curriculum are the life cycles of plants and animals, the water cycle, day and night, seasons, breathing, migration, ocean waves, tides, and the rock cycle. Cycles from social studies have also provided extensions of these lessons, and openings for students to develop lesson plans for their fieldwork that assist children in examining and representing cycles.

At lower grades non-numerical representations of cycles, such as a schematic diagram of an insect's life cycle or an illustration of the sequence of phases of the moon, are more appropriate than representations calling for the interpretation of numerical information.

When discussions of cycles lead to graphing, comparisons of graphs can contribute to teaching the concepts of period, minimum, and maximum. Further discussions of cycle graphs can lead to comparisons between cycles in terms of these values. For example, is the cycle of daily air temperature (night and day) more extreme or less extreme than the cycle of monthly average high temperatures? By examining the cycle of pennies in your pocket, can you determine the maximum number? Is the pattern similar for women and for men? If not, why not?

The shapes of cycle graphs will also vary, with gradual and rapid changes and relatively more regular or less regular changes. The graph of the number of socks in the laundry basket has a gradual part and a rapid change part. Is the increase gradual or rapid? Is the decrease gradual or rapid? Why? Why is the decrease of lemmings in its population cycle rapid? Why is the period of change of political control of the U.S. Presidency irregular?

In investigating cycles we have the opportunity to describe systematic changes. We come to know the forces that bring about those changes through the evidence they leave. We have the opportunity to make inferences about cause and effect. Students who have engaged in this kind of analysis of trends and cycles will be able to distinguish between these patterns. A final pattern of changes is also important in children's science learning.

Random Events

Many changes in science show random influences. These occurrences are seldom studied in the elementary science curriculum, yet in understanding scientific evidence it is important to consider the possibility that data do not reflect a trend or cycle, but rather a random pattern.

Again, experience with real examples assists preservice teachers as well as their students in later recognizing novel cases of random outcomes. Familiar childhood examples occur in games children play, including dice games and the nonverbal games "Scissors, Paper, Rock" and "Guess the Hand with the Stone." Familiar instances of random outcomes in science are found in genetics simulations. Here, even though the overall average outcomes can be predicted, individual outcomes are unpredictable.

Experiences with random outcomes can assist children in developing the scientific attitude of accepting uncertainty. This is an underdeveloped attitude in children, and in many adults.

Applications of Patterns of Change in Lesson Planning

Throughout these experiences with patterns of change, content examples are drawn from life, earth, and physical sciences. Small cooperative groups of preservice teachers construct two sets of trend, cycle, and random examples: one drawn from their own experience, and another set of examples drawn from common childhood experiences. These examples are available for them to use as they plan to introduce the same concepts to children.

Toward the end of the term, as preservice teachers plan a unit of science instruction, they choose a theme that can be supported by the unit content and express that theme in their lessons. The unit planning assignment is complex, and integrates essentially all of the pedagogy taught in the methods course. Within this assignment the preservice teacher identifies one of a list of themes that his or her unit will support. Then lessons are constructed to support the learning of the unit content and also to exemplify the theme.

Extending the Ideas to Other Themes

The above presentation of Patterns of Change as a theme in science instruction is intended as an example. Trends, cycles, and random events can appear and reappear throughout the curriculum at a grade level, and serve to bind together units of instruction that might otherwise have an isolated aspect. Where a theme is incorporated into the curriculum, the units of instruction take on an extra importance as sources of examples to support the larger idea of the theme.

The theme can be present as a modest part of a given unit. Still, the cumulative effect of repeated experiences with the theme reappearing in life, earth, and physical sciences during various topics taught during the year assist the

child in developing a "superstructure" of meaning. That background is available as the child experiences new content. Because the learner experiences this "big idea" of science in varied forms it may be possible to begin to generalize and use the idea in new contexts.

Additional themes suggested in the *Science Framework for California Public Schools* (California Department of Education, 1990) include energy, stability, scale and structure, evolution, and systems and interactions. That document recommends that two themes be exemplified in the curriculum each school year. Any of these themes or others that could be identified will add a richness to the child's science experience.

Thematic teaching supports science education in the three areas of content, process skills, and scientific attitudes. Content learning is enhanced through meaningful connections and organization of memory. Process skills, including observing and inferring, management of data, and pattern finding, are accomplished through hands-on and minds-on activity. Attitudes including curiosity, objectivity, and willingness to accept uncertainty are advanced through high engagement, and appropriately challenging puzzles and investigations.

Preservice teachers cannot be expected to use thematic instruction spontaneously or simply as a result of a presentation of its characteristics and virtues. Recurrent experiences with a theme in the elementary science methods class, particularly if integrated into a variety of activities throughout the term, will provide a sound foundation for these teachers to recognize, value, and practice thematic instruction.

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Helping Science Teachers Develop Effective Classroom Groups

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Classroom groups for hands-on science can work effectively or they can "work" disastrously. The key to effectiveness is in attention to group dynamics before the groups are given content learning. This paper will describe the process used in science methods classrooms to teach pre-service teachers how to develop effective classroom groups. Too often teachers try using groups but give up when they find the groups ineffective and out of control. The skills to manage and control K-12 students is a prime concern for pre-service teachers. The procedure described here gives the science teacher a plan which is based on theories of group dynamics which train the K-12 students to work together effectively. Once the groups have been developed, it makes little difference what the configuration of the group might be. The group members will have learned to manage their own group behavior because their needs for belonging have been met. A positive classroom climate will be the goal for these science teachers. Schumuck and Schumuck (1983) define this climate as one:

> ...where the students expect one another to do their intellectual best and to support one another; where the students share high amounts of potential influence-both with one another and with the teachers; where high level of attraction exist for the group as a whole and between classmates; where norms are supportive for getting academic work done, as well as for maximizing individual differences; where communication is open and featured by dialogue; where conflict is dealt with openly and constructively; and where the processes of working and developing together as a group are considered relevant in themselves for study. (p.30)

The interpersonal needs of inclusion, control, and affection must be met by the participants if the positive climate is to prevail. This climate should be established before the science student is asked to do hands-on group learning.

For easy reference, the approach described will be divided into four sections: One: Orientation; Two: Building Group Responsibility; Three: Initial Group Activity and Review; Four: Effective Cooperative Learning.

Orientation

The first elementary science methods class of a new semester begins with the statement that the goal for this class will be to experience a positive classroom

climate. If that climate is established, the students will find they will share control with the teacher. The Schmuck definition of "positive classroom" is given. Philip Shambaugh's 1978 study (cited in Schmuck, 1983) suggests that the interpersonal needs should be addressed during the first meeting. They can be met by: (1) giving and receiving information about others, (2) exchanging opinions and asking questions about another's statement, and (3) expressing pleasant feelings and decreasing any criticism which might have occurred. The goal and the elements needed to reach the goal are shared with the science methods students so they can follow the process they are using and may later use with their own classes.

Day 1 - Introduction

After a brief introduction of the course content, details are promised for a later date. The main activity of the first day is a focus on building the positive classroom climate. The instructor's introduction gives more attention to personal attributes than academic attributes. The purpose is to stress that the instructor, along with the students, is an active class participant who wants to share the power of leading. The usual background is given, but items that allow the students to know the instructor personally are included. I have found an "ice breaker" to be a reference to my traumatic 49th birthday and the year it occurred. "She's *that* old! and she admits to trauma?" are the expressions I read on their faces as we laugh together.

Stanford (1977) maintains that all students need to know answers to the questions: (1) what is this class about? (2) who is in charge? (3) who are these other people and where will I fit in? The need for inclusion, referred to earlier, must be met. Once the methods class content and instructor have been briefly introduced, the students find out something about these other people and they begin to find out how they will fit in with these people. They are asked to divide a sheet of paper into four parts and to write or draw a different piece of information in each of these sections. Beginning in the top left they write the name they want used when being addressed. The top right shows their favorite subject while they were in elementary in school. The bottom left shows their greatest accomplishment to date, and the last section lists three things for which they want to be remembered. The point of this activity is to get the students to reveal a little more about themselves and what they value. Additional ideas for each phase of building effective groups can be found in Schmuck and Schmuck (1983) and Stanford (1977). The students then count off by four or six, depending upon the number in the class and the time available. Larger groups take a longer time for everyone to have an opportunity to speak. All the 1's will make up one group; all the 2's will make another group, and so forth. This method of grouping insures that students sitting together will be in different groups. At this point a signal is introduced. The signal will be used when attention needs to be redirected back to teacher. This addresses the concern teachers have expressed about not being able to regain control once students are in groups. It has been found that if the class

knows the teacher's signal before they ever move to groups and the teacher uses the signal, student attention is refocused without loss of control. The key is to use the signal and *wait* until all have responded. The silent signal I find effective is to lean on the chalkboard with my raised arm being the prop. This signal is easy to see. It gives the teacher a place to rest while waiting for attention to be refocused. The signal is used for as long as is needed at first. It is most important to model the signal and *not* shout over the class. With the signal established, the instructions are given for interaction within the groups before the students move to their groups. No one moves until after the instructions are given. Here, again, the teacher does have control and must be consistent in using this leadership role. If anyone begins to move, the teacher stops talking and waits. Peer pressure will usually stop the mover and then attention will return to the leader. The instructions include whatever the teacher wants done related to the four pictures. They can be asked to question each other if the name chosen is unusual, find how many preferred science while in elementary school, find a way to relate their area of accomplishment to leading elementary students, and note which of the things they want to be remembered show attributes that will help them to work cooperatively with students in science. These instructions should help the participants feel the inclusion, control, and affection needed to build the positive classroom climate. The leader for each group is assigned at this point. The leader is based on an outrageous catagory such as "the one who is shortest", or something equally unimportant. All the leader is asked to do at this stage is to be sure everyone shares so that all begin to feel included and have some control in the group. Specific directions are given about where each group is to be located so confusion upon moving is kept to a minimum. After everyone in each group has had an opportunity to share I signal for quiet. The final instruction is to ask the leader to have each member of the group describe how effective the group was in helping the participants feel a part of the group. Group members usually use an adjective (e.g., helpful, interested) to describe the group and its interaction. If the group members need to discuss the reactions, they may do so at this time. Upon completion and the signal for quiet, the process is reviewed. Students are asked to identify each step and give their understanding of the necessity of each step from the signal, the group formation and leader choice (usually they add the possibility of assigning other roles within the group and we discuss the advantage of so doing), assignment of group space, and a clearly described task for the group. Special attention is given to the final activity that gives participants a way to praise the group but, also, to let the group know that some needs have not been met. This is essential to providing each member a way to feel included and to have a degree of control. A beginning has been made for the "minds-on" aspect of hands-on science as each participant is asked to think of how to make the group process work so the doing of science in groups can progress effectively. The students are told that we will continue to build this classroom climate in the days ahead, and that this will lead to group work with hands-on science where all should feel comfortable enough to do their best while working with others.

An addition to this first day activity would be to ask the pre-service teachers for their ideas of what they would ask the elementary age science students to share in the "four section" assignment. This could be a done on the second day after the pre-service teachers were familiar with ways to develop the positive classroom climate. With college age students I have used only two activities, the one above and the next one referred to in Day 2.

Day 2-Continuation of Orientation for Inclusion

A variation of the "Double Circle" (Stanford, 1977, p.61) activity is used at the beginning of the second class. The class numbers off by fours. The 2's form one circle and face outward. The 4's form a similar circle at another place in the room and face outward. The 1's form an outer circle around the 2's and face inward so there is a one-to-one correspondence. The 3's likewise form an outer circle around the 4's. The signals this day are hand claps (this activity gets to be very noisy so a sound signal is needed). A question is given that each one will answer to the partner facing them. When the "move" signal, a single clap, is heard one of the circles moves to the right one person so new pairs are formed. They continue to answer the same question given until all in the outer circle have met all of the students of the inner circle. Here a double clap signal is used so students can hear me give the next question. These questions become progressively more self revealing. I have found three rounds work well. In round one the students introduce themselves and tell what they would change their name to and why they would make the change. (This question is chosen purposefully as a silly way to break the ice). In the second round students try to call the other by their real name and tell what they would use $100 for if it was given to them. Students must also explain why they would make their choices. In the third round they again speak to the other by name and give themselves a compliment by telling what they are good at doing. My students find this last question to be quite threatening. There 's dead silence for a short period after the question is given. When we discuss what has happened in this activity, students recognize a progression in the questions and how that progression has caused them to get to know one another at successively deeper levels. The final question, although the most difficult, is the one they like best for they feel included and valued and they have controlled what is revealed. The students feel affection for the others because of the sharing, but also good about themselves because they have had a forum for self-affirmation. In small groups they may discuss the questions they would use with the elementary students. This activity takes no more than 10 minutes so other content matters can be a major part of the class period. Whenever an activity is done it should be processed, using questions about the effectiveness of the activity for building the positive classroom climate. Processing is done so the class members understand why the activity was done and how the discussion, the processing, can be used for building the climate they will be seeking to establish with science classes in the future.

Building Group Responsibility

To demonstrate how members can help or hinder group work, we move into the second stage. The next activity is a "Fishbowl" where half of the class will be observing the other half. This day I ask people who have previously indicated an interest in similar areas of science to sit in an inner circle and those with an interest in other science disciplines to sit in an outer circle so they are observing the "fish" of the inner circle. (Any division which fits the methods teacher's goal which will begin to group students who will work together in cooperative hands-on/ minds-on science in the days ahead may be used) They are told that the group in the center will be discussing when and why hands-on science is not effective in the classroom. Later the groups will switch places and the outer circle will become the "fish" and will discuss when and why hands-on science is effective in the classroom. While the students in the inner circle gather their thoughts, students in the outer/observing circle are addressed. The observers are given a handout with guidelines to follow. The guidelines indicate that they are to observe and note who leads and facilitates, how this is done, how often some participants interrupt others to speak, and the extent to which everyone is included in the discussion. The observers also are to determine how participants show they are listening (e.g., nodding, smiling, paraphrasing, and looking at the speaker). The climate of the group is to be observed by how the participants are sitting, attending, and participating. This handout is used to clearly guide the pre-service teachers to identify what is needed to facilitate inclusion for leaders and all participants. With no knowledge of the guidelines and with no appointed leader, the inner circle is asked to begin discussing when and why hands-on science may not be effective in the classroom. This procedure forces the class to observe the behavior found in a leaderless group. The group generally flounders through the 5 minutes allowed for this activity. Often a natural leader emerges and dominates to the frustration of other natural leaders who either try to interrupt or give up to "let the other do it." The results are all too familiar to many of the students. When I call time, the outer circle, in as positive a manner as possible, critiques the inner circle's interaction. I have put the guidelines on the overhead at this time so the inner circle can follow them. Through this critique I facilitate the discussion to lead to the conclusion that an effective group needs a leader/facilitator who knows what is expected of him or her and participants who know how to bring about input from all. Then the "fish" move outside and the outer circle moves inside. This time I choose a leader to facilitate the discussion of when and why hands-on science is appropriate in the classroom. Of course the discussion moves along nicely with no one dominating or sitting back uninvolved. All feel a responsibility to the group and know how to encourage everyone to participate. In conclusion, each group "processes", by discussing implications of this activity for facilitating group work among elementary science students. If the pre-service teachers have ideas for modifications in order to build more effective group behavior with the younger students they are encouraged to make their suggestions. It is important to involve the pre-service teachers in expressing their ideas along with their

reservations about building effective groups. They have many worthwhile additions to the process that specifically address hands-on/minds-on science, such as the roles played by the elementary participants (e.g., materials manager, timer, writer, safety officer). If reservations about working with groups are not expressed and dealt with, teachers will not use group activities in their teaching. It is possible to have students write about their reservations which can be addressed during another class period. When they reassemble, the small groups may discuss the reservations that might be perceived in hands-on science teaching with elementary age children. The sharing of the results of the "processing" (in this case with a specific focus on their reservations) done by each small group is reported and discussed by the class as a whole. This process is used to allow the class to experience how small group discussions can lead to whole class learning when the suggestions and reservations of each group are brought to the class as a whole.

Aronson (1978) in *The Jigsaw Classroom* advocates training a few leaders and a few recorders to begin group work. I have chosen, instead, to help the whole class learn the roles of leader and recorder together so each participant may understand why a person is behaving as they do within the role given to them. It is emphasized that leader/facilitators (or other roles designated by the group) will be changed from time to time so all need to know how to behave in each role. This has been successful with third graders as well as pre-service teachers.

Initial Group Activity and Review

Determining the Best Buy

As soon as possible after the Fishbowl activity a problem solving, cooperative group activity is given to the small groups to allow the students to experience the "training" received through the Fishbowl while they are problem solving. It is helpful to find a short exercise that is sure to bring about controversy. One exercise which can be effective is the "Best Buy Paper Towel" experiment. Each group is given 3 different unnamed brands of paper towel and they are to decide which is the best buy. Materials that groups might want to use in the testing (such as containers, water, window cleaner, etc.) are made available for selection. The group's report back to the class as a whole must include the conclusion (which is the best) and all the evidence and arguments which support that conclusion. They must select those who will fill different roles including the "leader" and a "recorder/reporter" who will be designated to report the group's conclusions to the class as a whole. This activity does generate discussion so the leader is challenged to be sure no one gets left out when most are talking. Once groups are actually solving a problem cooperatively there may still be disagreements which are not easily resolved. This is the most effective time to have the whole class talk about conflict resolution. Another issue which arises in some groups is the need to know more information from the teacher. They find that only the leader can leave the group to ask for something and, hence, that all must communicate their

needs to the leader. After an appropriate amount of time I signal for refocus and ask for reports. This activity allows for different strategies and solution , all of which can be equally correct. We find that some groups get bogged down or cannot resolve a conflict in the group or do not seek help from the teacher. Cooperative groups will work well after learning effective group behavior but there will be times when more guidance and conflict resolution will be needed. Although there are a number of conflict resolution strategies which teachers might use (Stanford, 1977, chap. 8), I facilitate conflict resolution in the student groups by having each pair in a group identify what it can do to make the group work more cooperatively. Each pair then reports to its group and all decide on what should be done to improve cooperation. This technique places responsibility for conflict resolution back on the group members and further facilitates learning to work in groups. My students find this to be an effective strategy and tend to use it in their teaching.

Processing the Group Interaction

The processing of the group work becomes a separate focus on this first day of hands-on, cooperative group work. Group processing, if done in a thoughtful, guided manner, increases the likelihood of minds-on group work taking place. Previously, students have been asked to think about how the groups worked and to describe their reactions with a pointed adjective. This day, written guidesheets, which include specific questions, are given to each member of the group. Basic beginning level questions are: Who was involved and how was this shown? Did each one feel they had control of part of the experiment? Were all of the participants approved and acknowledged within the group? What could the group do better next time after hearing answers to these earlier questions? The generality of these questions allows the students to respond for themselves and for their peers with little threat. (Samples of these guidesheets may be found in Schumuck and Schumuck, 1983, (pp. 51-51) It is the role of the leader to encourage all members to become involved in processing the work of the group after each session. If time is very short, they need, at least, to get each member to give the group a description of his or her preception of that meeting and the one thing the group could do differently to improve cooperation. By making the processing of the group a separate focus, the importance of open communication for effective group work is emphasized. If a leader notices that the communication does not seem to be open and is not able to get a member to participate, the leader needs to work with his or her group or consult with the teacher for assistance. Again, effective group work does not just happen. It is carefully planned, trained, and the teacher has a role of "guide on the side" at all times.

When the processing is completed, I ask each group to share with the class as a whole one thing from their group that would improve cooperation within their group. Sometimes there is nothing to be improved and that would sound ideal. Those who do have a suggestion are the groups which are more likely looking at themselves more realistically. Either way, as facilitator I can comment positively

on progress in using cooperative learning effectively. As with previous phases in the building of effective science cooperative groups, the pre-service teachers make suggestions for group processing with elementary students which may be different from what they have done in the methods class. They also discuss problems they preceive in processing with elementary students. Together the groups make suggestions that address the problems and add to the fund of knowledge for minds-on, cooperative learning. Group processing is needed if cooperative learning is to be effective. By making it a separate focus, giving written guidelines to be used each time hands-on cooperative groups are used, and setting aside time for the process, the pre-service teachers realize the importance of this activity and use it in their own elementary science classes.

Effective Cooperative Learning

With the training and building that have occurred in the early days of the semester, the class is now ready to use cooperative learning strategies for their own learning and will know how to prepare the science classes they teach for cooperative learning. As students review *Circles of Learning: Cooperation in the Classroom* by Johnson, Johnson, and Holubec (1984) and *The Jigsaw Classroom* by Aronson, Blaney, Stephan, Sikes, and Snapp (1978), they recognize many of the steps we have taken in class to build effective groups. The pre-service teacher now knows a great deal about building effective groups for use with hands-on science activities.

I have tried to structure assignments to include the strategies referred to above and strategies found in *Group Investigation* by Sharan and Kussell(1984). Usually, each methods assignment has small groups contributing to a whole class project. For example, Jigsaw is used to review curriculum materials and textbooks. Each group prepares a presentation on one program and "teaches" this program to the other groups. *Strategies from Circles of Learning: Cooperation in the Classroom* by Johnson, Johnson, and Holubec (1984) are used when students prepare three hands-on/minds-on activities, each from three different grade levels. Each group then presents these activities to the other groups. A group investigation approach is the basis for the development of a hands-on activity which integrates science with other elementary subjects while providing for different learning styles. After the projects are completed each group does a written assessment of the group work. This is given to the instructor and is used by the instructor to identify areas where help or remediation is needed. Most of the time the groups show how much they have learned together and how responsible they feel toward their group. Each year I have found a disfunctional group through this written assessment. I talk with each member and ask for information about the behavior of the group. Usually, the members do not need my offer of conflict mediator because they identify that they need more open communication within their group and proceed to use the solution they have identified. Students in the disfunctional group learn the most about effective group training. In reports, on the final test, the disfunctional group seems more

aware that effective group work needs teacher involvement along with careful training of the participants. All groups report that while learning the content of science methods they have learned a great deal about working with others and the need for honest communication. The building of the positive classroom climate was the key for the pre-service students. They now know how to build for effective hands-on science classes when they begin teaching.

Stanford(1977) refers to the last stage in the life of a group, the termination stage, as one when sadness and anger will be displayed. The students have become closer as they have learned to listen, learn, and resolve conflict together. The termination stage is an opportunity for feelings to be openly expressed. To facilitate a termination, each person is given an opportunity to say how they feel about the learning which has occurred in the class. This class is the semester immediately prior to student teaching. It is a frightening time, and many find freedom during this final activity to express their fears and hopes. We have learned to effectively work together. We have learned to support one another through the building exercises and we know the value of honest expressions of feelings and ideas. The positive classroom climate has allowed us to do our best while working together to prepare for the future.

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Using the Learning Cycle to Introduce Cooperative Learning

Alan Colburn

Teachers teach as they were taught. Thus, modeling is a powerful strategy available to the methods instructor for changing preservice teacher behavior (Gliessman, 1981). We must, therefore, pay careful attention to what we *do* in the college classroom.

Cooperative learning and the learning cycle are two instructional strategies I encourage preservice teachers to use to address some common educational goals. Consequently, it is imperative I model the use of both these strategies in my methods course. One way involves modeling a variety of cooperative techniques, while sequencing my instruction using the tenets of the learning cycle.

The Learning Cycle

The learning cycle is a flexible instructional model usually defined in terms of three phases of instruction. The *Exploration* phase, broadly defined, features student investigation of phenomena, with minimal guidance from the teacher. Ideally, this phase provides students with the opportunity to experiment with objects and ideas, and leads them to the construction of a new concept. In the *Concept Introduction* phase of the cycle, the instructor helps the students formalize and clarify their thinking from the Exploration phase and introduces students to the new concept(s) they explored previously. In the *Application* phase of the cycle, students expand their knowledge by using newly learned concepts in different situations. The Application phase may introduce students to new experiences, therefore acting as an Exploration phase which begins a new cycle.

I suggest readers unfamiliar with the learning cycle examine the NARST monograph on the topic (Lawson, Abraham & Renner, 1989). Alternatively, the teaching model recommended by the National Center for Improving Science Education (1991) or the BSCS 5-E model ("explore, engage, explain, expand, evaluate") (BSCS, 1993) are both virtually identical to the learning cycle described here, and are appropriate sources of further information.

Using the Learning Cycle to Introduce Cooperative Learning

Exploration

Students are pedagogically introduced to cooperative learning via what Kagan (1992) calls the "structured" approach. Students experience a variety of small activities, each of which illustrates some or, eventually, all the elements of

cooperative learning (interdependence, individual accountability, developing social skills, students simultaneously active).

All the activities are relevant to course goals *other* than those associated with cooperative learning, however. In other words, the activities demonstrate cooperative learning techniques while teaching about other things. I ask the reader not to confuse cooperative learning strategies and content *about* cooperative learning.The idea of cooperative learning and its elements is not formally introduced to students until later — the concept introduction phase.

Here are some examples of small activities illustrating elements of cooperative learning. I use Kagan's (1992) names:

Numbered heads together

Students in a team number off from one to four. The teacher asks a question or gives directions (*e.g.*, "make sure everyone on the team can explain the differences between the exploration and application phases of the learning cycle"). Team members put their 'heads together' to make sure everyone knows the answer. The teacher calls a number, and the student in each team who has that number needs to be ready to give the answer.

Numbered Heads Together is usually used as a way to review or master basic information. A methods professor, for example, could ask students a question about the differences between concrete and formal operational reasoning. Rather than merely having one student answer the question, Numbered Heads Together increases the likelihood that more students will be involved in formulating a response. This latter aspect of cooperative learning is often called "simultaneity."

This cooperative learning technique, however, is not limited to review. An elementary teacher, for example, could tell a class "Make sure everyone on your team can make a light bulb light, using all the materials you've been given." Students still work individually, but their teacher encourages them to help and teach each other.

Blackboard Share

This is used with other cooperative learning structures as an alternative to traditional presentations. One member of each team goes to the blackboard. Teams simultaneously post their best response to a question, problem, or data from a laboratory exercise. The structure illustrates simultaneity.

In doing a science activity, for example, one student from each group would write their data or results on the blackboard. This lets students immediately compare their results with others, and allows the teacher to conduct a lesson that does the same thing.

This, and several related techniques, are all useful in the methods classroom as well. For example, journals and short writing assignments are popular in methods courses. Students make one or more photocopies of an assignment to

give to others for peer review. Students can then simultaneously receive responses from peers.

Three Step Interview

Students interview each other within their groups to find other's opinions or ideas on a topic given by the teacher. They interview each other within pairs. Each of the members then tells their team of four what they learned from their partners.

The interview questions can be, basically, anything. Here are some selected examples:

- What do you most want to learn about the learning cycle?
- What experiences have you had w'th ...?
- As a teacher, how would you find ... useful?
- What did you learn from the lesson?
- What is still unclear to you about this lesson?
- How did you go about solving [a given problem]?
- How would you test that idea?
- How would you explain the differences between your results and those of another group?

Think-Pair-Share

The teacher poses a problem or question to the class. Students take a moment to think about a response, and then talk their ideas over with a partner. Comments are then shared with the class. This technique incorporates the element of simultaneity, while giving students a chance to think about and rehearse a response. It is especially valuable for students who are sometimes hesitant to speak in front of the whole classroom group because they can "try out" their ideas in front of one person before speaking to the whole group.

Think-Pair-Share is, obviously, and is also easy to use and is also popular. A teacher can use the technique virtually anytime she or he has a discussion or asks the class a higher order question. Common variations include:

- Students Sharing with team members, rather than the whole class (rather similar to Numbered Heads Together);
- Jotting down their thoughts before talking them over with a partner, adding a small amount of individual accountability, because every student writes something;
- Doing or building something (*e.g.*, clay boats) before talking it over with a partner.

Jigsaw

Aronson's (1978) Jigsaw technique is a popular and straightforward cooperative learning technique valuable for helping students understand content and — with teacher guidance — learn social skills. Each student in a team is assigned something different upon which they become an expert. Students meet with members from other teams ("expert teams") who are assigned the same topic. These expert teams help each other understand and consider how to teach about their topic to classmates. Students return to their original teams ("home teams"), and each teach the others their topic. Students are responsible for learning all parts.

The Jigsaw is particularly good for preservice teachers to learn because it: (a) incorporates all the elements of cooperative learning, (b) is highly structured and straightforward, and (c) is particularly useful for teaching and reviewing content learning, common goals in most classrooms.

Any assignment that can be broken into independent parts can be structured by the teacher as a Jigsaw activity. For example, a textbook assignment is broken into three or four sections. Students within a (home) team are assigned particular sections of the assignment in which they are to become experts (with help from members of their expert team). Experts then go back to their home teams to help members better understand their assigned section of reading.

Alternatively, students can all be given the same reading assignments, but asked to examine the works from different viewpoints. Methods students, for example, could read a study about schooling and then be asked to view the research through the eyes of a teacher, principal, parent, and pupil. If the class is ambitious, expert team members could interview people from one of these groups. When the experts return to their home teams, each person in the group will have something unique to contribute to other members.

One of the questions that arises at this point is when should students be formally introduced to the various cooperative learning techniques discussed previously? In other words, when do students learn about how to teach using the Jigsaw or Think-Pair-Share, for example, as opposed to merely being a student who is being taught by someone else using the techniques? Do students learn right after they have experienced the techniques (during the exploratory phase of the cycle), or does the instructor wait until students have been formally introduced to content about cooperative learning (during the concept introduction phase)? Either approach has merits. The first possibility mentioned probably offers more of a "how-to" orientation; students could be asked to plan their own Jigsaw or Think-Pair-Share right after being introduced to a technique. The second possibility fits well with thinking about learning and constructivism; the instructor insures that students have had plenty of concrete experience with a new idea *before* they receive a formal introduction to the idea. Thus, the decision about when to tell students about cooperative learning techniques, like Think-Pair-Share and the Jigsaw, will depend on the instructors goals in his or her methods course.

Concept Introduction

After teaching methods students using activities like those illustrated above, I formally introduce preservice students to the three major elements of cooperative learning: positive interdependence, individual accountability, and the teaching of social skills. Two other elements, students working face-to-face and at the same time (simultaneity), are also eventually mentioned.

I've written textual information about the three major elements of cooperative learning (see Appendix), and teach this information using the Jigsaw technique. In groups of three (home teams), students are each given a handout which describes one major element of cooperative learning.

Students read their handout and meet with others who were given the same information (expert teams). Members of the expert teams help each other understand the handout's content, decide which information is most important for others to know, and devise strategies for teaching their classmates about their sheet's content.

Finally, students return to their home teams and teach each other about the elements of cooperative learning. A whole class discussion occurs afterwards in which I pose common classroom situations to students and ask whether the scenarios represent "true" cooperative learning. If the students judge a scenario as not being representative of cooperative learning, they are asked to change the situation to make it more representative of cooperative learning. This after-Jigsaw discussion is an appropriate time to continue to use examples of techniques mentioned above, like Think-Pair-Share.

Alternatively, students can be given written classroom scenarios and be asked to change the scenarios to incorporate more of the elements of cooperative learning. As with the discussion above, this assignment would follow the Jigsaw activity. This assignment then serves as a way to hold students individually accountable for learning the content about cooperative learning presented during the Jigsaw activity.

Application

In our methods course at the University of Iowa students use their new learning as they participate in an intensive three day team-teaching experience. The experience is intensive because each of the three days is videotaped. The experience incorporates all the elements of cooperative learning — including most importantly the fact that the preservice students must work together in planning and implementing their lessons (positive interdependence), but at the same time are critiqued as individuals (individual accountability). Before and after the experience, we discuss the kinds of social skills they need to use for their planning and teaching to be successful. Their reflections on the experience help them understand the kinds of frustrations their own students will feel when learning to work cooperatively.

With or without access to this kind of experience, after being formally introduced to cooperative learning, students can be required to plan and teach short cooperative lessons within a practicum or student teaching setting. This is an excellent application because students apply the knowledge they have learned to a new situation. At the same time, however, they extend their knowledge about cooperative learning by experiencing first-hand what happens when they are the teacher using cooperative learning. They must ultimately modify what they learned about cooperative learning pedagogy to suit the uniqueness of the settings in which they are teaching, while at the same time preserving the elements of cooperative learning. Doing this requires students to use what they learned previously in new ways and new settings — the essence of application.

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APPENDIX

Handout #1

TEACHING COOPERATIVE SKILLS

Students who have never been taught how to work together effectively won't necessarily be able to do so. It is not uncommon for teachers to learn about cooperative learning, set up some nifty cooperative activity for their classroom, turn the students loose, and find that it does not work the way it is "supposed" to. Teaching cooperative skills — called leadership skills in the business world — is often an important prerequisite for learning; achievement will improve as students become more effective in working with each other.

There are several important assumptions underlying teaching students cooperative skills:

1. **Cooperative skills have to be taught.** 'Setting up' groups and then 'allowing' students to work together guarantees nothing. Learning cooperative skills is no different than learning how to use a microscope or write a complete sentence. All skills are learned in basically the same way.

2. **It does not make much sense to teach students skills if they are not going to use them.** The awareness students have of the need for cooperative skills is directly related to them being in cooperative learning situations. In other words, your efforts will be kind of wasted if, afterwards, you expect students to work alone without interacting with each other.

3. **Peers are important.** After students know what the cooperative skills are and are encouraged to practice them in their groups, peer support and feedback will determine whether the skills are used appropriately and frequently enough for them to become natural and automatic actions.

4. **Peer pressure to learn cooperative skills should be coupled with peer support for doing so.** There may be groups members who want to dominate, who are shy and afraid to participate, who become angry when they give a wrong answer, or who feel embarrassed by having the group realize they do not understand something. Group members need to know how to provide constructive support for the student to become more skilled ... the implicit student-student messages would be 'We want you to practice this' and 'How can we help you do so?'

Johnson and Johnson outline a **method for teaching cooperative skills**. The method has, basically, five steps:

1. Do whatever you must to ensure that students see *the need for cooperative skills.*

2. Do whatever you must to ensure that students *understand just what the skill is*, and when it should be used.

3. Set up *practice situations* and *encourage mastery of the skill.*

4. Ensure that students have the time and procedures for discussing (and receiving feedback on) how well they are using the skill.

5. Finally, ensure that students *persevere* in practicing the skill until it seems a natural action.

Handout #2

INDIVIDUAL ACCOUNTABILITY

To encourage students to learn, they have to know they will be held individually responsible for learning whatever it is you want them to learn. You do not want to have some students coasting along, doing nothing, while others do all the work. To avoid this, cooperative learning activities should be followed by something that holds students individually accountable: an individual quiz, a report, a demonstration or a final product of some type that is to be collected.

In some cases, each student may do something like take a quiz after the group session. In other cases, where something like a quiz is not necessarily called for, several student's names may be drawn from a hat and (only) their papers checked. In both cases, student's concern levels are raised. Someone, if not everyone, will have to demonstrate they understand whatever it is they are supposed to understand.

Several techniques, in fact, are available to hold students individually accountable for learning. For example, you can randomly call on students to explain a process, give a summary of the main points of a reading or discussion, etc. You can insure randomness in who you call on by using a 'shuffled' deck of 3X5 cards with student names on them.

Another possibility is the multiple response technique. This is used to both hold students accountable and check for individual understanding. The teacher can present a problem of some sort, call for a short silence period (to give everyone a chance to think), and then ask students to hold up a 3X5 card with the number 1,2,3, or 4 written on it (corresponding to one of four responses written on the blackboard or overhead).

When students fail tasks, the teacher steps in and shifts the responsibility to the group for not adequately preparing or checking all the members of the group. This can be tricky, though, because you don't want to ostracize individuals within a group. You just want to encourage groups to take responsibility for helping each other, and possibly structure things so that individual students (who otherwise might not have been motivated) decide to "learn stuff" so they won't let the rest of the team down. I should also point out that encouragement (praise) can also be directed at a small group, rather than an individual, when appropriate.

Handout #3

POSITIVE INTERDEPENDENCE

One of the attributes of 'real' cooperative learning is that classroom activities are structured so that small groups of students *must* work together. Students come to learn that "we're in this together — what I do effects you, and what you do effects me." They also, eventually, feel responsible for helping each other.

However, this kind of positive interdependence does not necessarily come automatically. That's where you, the teacher, come in. It is your responsibility to structure activities to encourage students to work together.

It is beyond the scope of this little activity to discuss different ways to foster interdependence. Instead, I will concentrate on one common method: the use of *group rewards*. Group rewards could be things like extra credit, token prizes, group recognition or encouragement, notes to parents, time saved used for something students like doing, etc. A key point to remember, however, is that the rewards must not be individual. *The reward must go to every member of the group (or class)*

So, upon what can you base this 'reward?' At the secondary level, it's common to base rewards on quiz scores. The group (or class) goal can focus on top scores, average scores, or the lowest scores. Rewards can also be based on improvement from previous efforts. For example, students can be rewarded based upon how much their scores on a test improve over their scores on a previous test or semester grade. The larger the improvement, the more points earned toward a reward. Rewards are given when the group reaches a particular number of improvement points. (To encourage those students who consistently receive high marks, a special bonus should also be present for a perfect score.) The advantage of this way of doing things is that students with the lowest scores, who need the most attention, are also the ones with the greatest potential to generate improvement points leading to a group reward. Peers can pay extra attention to the students who can most benefit from the attention.

Constructing Concepts of Constructivism with Elementary Teachers

John R. Staver

We discuss it so often in our Center that it has become known as the 'c-word.' In this context, 'c' stands for constructivism. Papers on constructivism abound at meetings of the Association for the Education of Teachers of Science (AETS), the National Association for Research in Science Teaching (NARST), and the American Educational Research Association (AERA). NSF funded curriculum projects such as the elementary and middle school science and technology curricula developed by BSCS (1992, 1994 a,b,c) and the *Full Option Science System* (Regents, University of California, 1992) developed at the Lawrence Hall of Science are based on constructivist principles. At almost every convention of K-12 science teachers and in most journals and magazines, elementary, middle, and high school science teachers are encouraged to teach according to constructivist principles.

Constructivism and Teaching Science

As a theory of knowing, constructivism is an integral foundation of the current reform movement in science education. However, the concepts of constructivism are quite abstract and often counter intuitive. For example, constructivism is a theory of the knower, not a theory of the external world. It seems quite fair, then, to ask how constructivism can be of any value in learning about the external world. Preparing teachers to teach according to constructivist principles is one matter; helping teachers to construct an understanding of constructivism as a way of knowing is quite another matter. Nonetheless, as science teacher educators we are compelled to do both because acquiring an understanding of teaching in terms of its relevant theories and research bases is central to the continuing professional growth of teachers.

My goal in working with practicing teachers in professional development workshops and graduate level courses is to: (1) Increase their understanding of specific concepts of constructivism; and (2) explain inqui[illegible] science teaching in terms of these concepts. Included are the following aspects of constructivism:

1. Learners actively construct knowledge using their prior knowledge.
2. Knowledge is represented by functionally adaptive ideas which fit with, but do not correspond to, the structure of the external world.
3. Constructivism is a theory of the knower and knowing, not a theory of the external world.

My purpose here is to describe how I introduce teachers to the three notions of constructivism listed above.

Constructivism in Action

The teaching model that I use is the five-stage version of the Learning Cycle - Engage, Explore, Explain, Elaborate, Evaluate - which was developed by BSCS for its elementary and middle school science and technology curricula (BSCS, 1992, 1994 a,b,c). BSCS calls this version of the Learning Cycle its Instructional Model; it is explained in detail elsewhere in this yearbook (Staver & Shroyer, 1993).

I use the 'Hum Dinger' activity from the *Full Option Science System*, FOSS, curriculum project (Regents, University of California, 1992) as an Engage and Explore activity. For readers who are unfamiliar with this activity, it is part of the grade 5-6 Models and Designs unit. I do the activity with teachers much as it is designed in FOSS. In the Engage phase, I ask a series of questions, first to check teachers' level of knowledge regarding constructivism, then to focus their attention on the activity. I ask, "Who has heard of the word 'constructivism'? Who knows what it means?" Teachers frequently indicate a familiarity with the term; a few refer to constructivism as a psychology or learning theory; only rarely does a teacher mention epistemology or philosophy in reference to my question. Next I place a red shopping bag made of synthetic material on my desk and say, "Today my intention is to introduce and discuss some theoretical notions and issues of constructivism that undergird exemplary elementary science teaching. In doing so, I start with a concrete activity so that we can relate the phenomena of the activity to relevant theoretical points."

Beginning the Explore phase, I then point out the bag and the string which emerges from the side of the bag. I usually say, "Please watch and listen closely as I pull and release the string. Tell me what you see and hear." I then pull the string, and a humming sound from inside the bag is immediately audible. After a few seconds I release the string, and a distinctive ringing sound can be heard. Teachers are immediately very curious, and they ask me to pull and release the string again and again. They point out that they can see very little except for me pulling and releasing the string. However, they report hearing a buzzing or humming sound when I pull the string. When I release the string, they report hearing a bell ring. At this point I ask, "OK, so how should we describe what is inside the bag?" Teachers' responses vary. Sometimes they attempt to describe the structure but quickly find this avenue to be a dead end because they are unable to see inside the bag. They eventually describe the device in terms of its sounds. However, as adults, they rarely call it a Hum Dinger. Thus, I introduce the device inside the bag as a Hum Dinger. Teachers typically respond with chuckles and laughter; I point out that the FOSS developers have incorporated some 5th-6th grade humor into the curriculum.

Continuing their exploration, the teachers construct a device that hums when its string is pulled and dings when its string is released. They work in three- or

four-person teams using the materials from the FOSS Models and Designs module. Included are items such as a two-piece wood base, copper wire, paper clips, string, D-cell, D-cell holder, small electric motor, wood sticks in three lengths, wood hubs, rubber bands, large paper clips, and wood clothespins. These items and an assembled Hum Dinger are shown in Figure 1, which is a reproduction and adaptation of drawings in the FOSS Models and Designs unit. The figure is reprinted here with permission of the *Full Option Science System*, Lawrence Hall of Science, University of California, Berkeley. A great deal of discussion occurs within each group as ideas are generated tested, modified, discarded, and replaced. Groups quite often observe what other teams are doing. If participants want additional items in building their Hum Dinger, I attempt to fulfill their requests. I move about the room listening to the discussions, asking questions, offering suggestions, but not giving answers. Teachers need perhaps 30 - 45 minutes to complete this task. When all groups have successfully built a Hum Dinger, I bring the Explore phase to closure by calling for their attention.

Beginning the Explain phase, I ask a member of each group to demonstrate the operation of the group's Hum Dinger to the others. A great deal of interaction generally occurs and often includes applause and cheers as each group conducts its demonstration and answers questions from members of other groups. When the demonstrations are completed, I begin to ask questions. The initial focus is on teachers' prior knowledge and how they used prior knowledge in building a Hum Dinger. My first question is usually something like, "What did you think about and discuss at the beginning of the task?" Responses vary quite markedly, but teachers often report that their groups talked about creating the 'ding' and 'hum' sounds. According to them, the 'ding' sound is rather easy to make; when rung by hand, the bell makes a ringing sound quite like the 'ding' sound inside the red sack. Creating a 'hum' sound is not so easy; someone usually tests the electric motor with the D-cell, but the sound of the motor is rather different from the 'hum' sound inside the red sack. Nonetheless, groups usually realize rather quickly that the electric motor is a key element in creating a 'hum' sound.

At this juncture, I point out to teachers that they are using what they know about objects, mechanisms, and sounds to organize their thinking, testing, and constructing. I then introduce the phrase 'prior knowledge,' describe it in terms of the activity, and emphasize the general notion of prior knowledge and its use in learning as a part of constructivist theory and an important consideration in teaching. Teachers readily agree that prior knowledge is important, and an extensive discussion sometimes follows as each group shares how specific items of prior knowledge were used to build a Hum Dinger.

I then ask them to think about which group has built the best Hum Dinger. Almost immediately, teachers say, "We need to look inside the red bag to find out what the Hum Dinger looks like." I respond, "You must decide without looking inside the red bag." In return, they point out that they must see inside the bag in order to compare their own Hum Dingers with mine. My next response is that their judgement as to which group built the best Hum Dinger cannot be made as a comparison of how well the structure of their Hum Dingers matches the

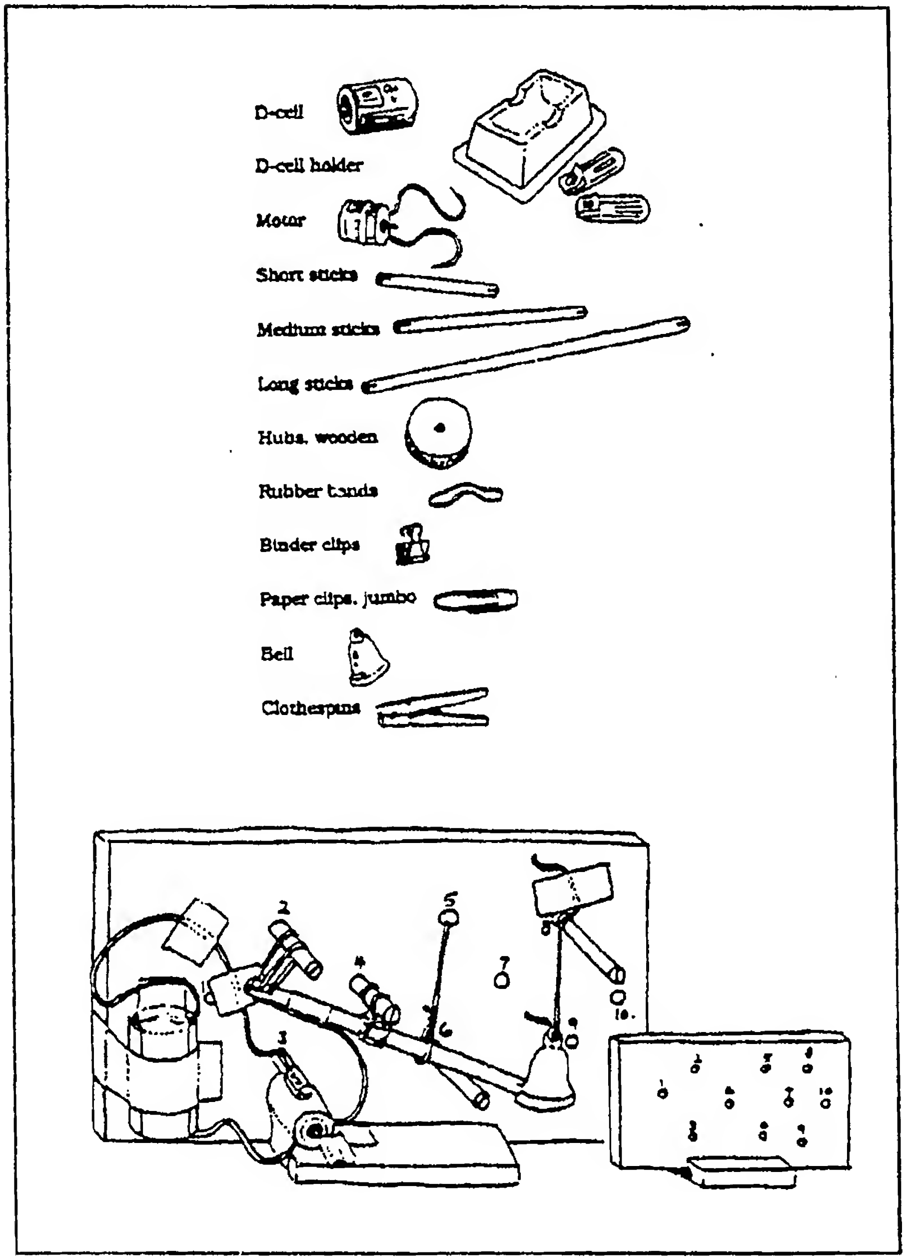

Figure 1. *A drawing of a working Hum Dinger and its components*

Note: Drawing reproduced and adapted with permission from *Full Option Science System*, Lawrence Hall of Science, University of California, Berkeley.

structure of the Hum Dinger inside the red bag. Rather, the judgement must be made on functional grounds; in this case, the hum and ding sounds that are made by their Hum Dinger as well as those of other groups.

At this point responses often diverge. Some teams give up, stating, "It can't be done if we can't see the Hum Dinger inside the red bag!" Other groups begin to inspect all the Hum Dingers more closely. I ask, "Can you work together to develop some criteria which you can use to judge the Hum Dingers?" Teachers can and do generate criteria which illustrate an extensive variety of ideas as to which is the best Hum Dinger. Typically they agree on two or three statements. Examples are: "It has to work three times. The 'hum' sound must be as close as possible to the 'hum' sound inside the red bag. It must fit inside a bag the size of the red bag. It must not 'hum' and 'ding' at the same time." Teachers then apply the criteria to determine the best Hum Dinger.

At this point I say, "Great! You have identified the best Hum Dinger without looking inside the red bag. Why did you feel the need to look at the Hum Dinger in the bag?" The nearly unanimous response is that they wanted to judge their own Hum Dingers according to which one of theirs best matched the structure of mine. I respond that the specific problem of deciding which is the best Hum Dinger is representative of a second theoretical issue. On one side is the traditional view that our knowledge corresponds to the outside world. A better correspondence means a better match of our knowledge with the outside world. In contrast, constructivism denies that our knowledge is a correspondence with the external world. Rather, knowledge is a coherent set of constructed ideas that fit and give meaning to our experiences, but do not match the structure of an external world that is unknowable in a direct way. I then point out that, from a constructivist perspective, the device inside the red bag represents the external world; the teachers' own Hum Dingers represent their constructed knowledge about the Hum Dinger inside the bag. Their experiences with the Hum Dinger in the bag are limited to the sounds that it makes. Although we have used the terms by now, I define the terms 'fit,' 'match,' and 'correspondence' in terms of the Hum Dingers. 'Fit' is defined in terms of a functional perspective. What fits is viable; it works. What doesn't fit is not viable; it doesn't work. Their Hum Dingers fit if they work like mine, which means that they make sounds similar to mine. However, a good fit in a functional sense does not imply that the structures of their Hum Dingers match with or correspond to the structure of mine. 'Match' and 'correspond' are defined from a structural perspective as being a conformity, agreement, likeness, or similarity with respect to structure. The stronger the match or correspondence, the more nearly identical are the structures. A perfect match or correspondence is represented in two identical structures.

Even after I introduce the definitions, teachers sometimes argue that the terms 'fit' and 'match' are essentially identical. If they bring up this point, I clarify their confusion in two ways. First, I reiterate the distinction between fit and match in an epistemological context as a distinctness in their perspectives. One is functional; the other is structural. Second, I present and discuss the lock-and-key metaphor that von Glasersfeld (e.g. 1984) has used extensively in

response to their point. I point out the functional connection between a key and a lock. Even if teachers have not raised the issue of fit versus match, I still present the lock-and-key metaphor because it, coupled with the other activities, is a vehicle for introducing the third aspect of constructivism. Von Glasersfeld argues that many different objects, including a key, can be used to open a lock. If these objects open a lock, then they fit it. Each object capable of opening the lock can be considered a key. The term 'fit' describes the functional capability of the key, not structure of the lock. Next, I establish a connection between the key and the knower, then between the lock and the external world. I point out that traditional views of knowledge focus on learning about the structure of the lock and the Hum Dinger inside the red bag; each represents the external world. In contrast, constructivism focuses on the functional capabilities of the keys and the teachers' Hum Dingers; each represents the knower. In summary, I introduce the focus of constructivism as the knower, the process of knowing, and knowledge as a functional adaptation. Again, I point out that constructivism does not focus on the external world.

There is little doubt by now that many teachers are either in a state of Piagetian disequilibrium or ready to say, "I don't believe or agree with this." My experiences clearly suggest to me that most teachers' views regarding epistemology can be classified as traditionally objectivist, in that they believe knowledge corresponds to the structure of the external world. Von Glasersfeld (1984) calls this view metaphysical realism. Bringing the Explain phase to a close, I review and discuss the three aspects of constructivism that I have just introduced. Readers should remember that my goal is to enhance teachers' understanding of certain specific ideas of constructivism, not to convert their epistemological world views in a brief workshop or even a one-semester graduate course.

Elaborations based upon the constructivist ideas explained above are extensive in number. Two examples are cooperative learning and inquiry instructional models (e.g. the Learning Cycle). Yet another elaboration, one that I will focus on here, is students' alternative conceptions and, of course, changing these conceptions.

Beginning the Elaborate phase, I focus teachers' attention on students' alternative conceptions by saying, "Regardless of whether or not you believe or accept the constructivist notions that I have just introduced, I want to spend some time discussing students' notions about science concepts which are at odds with current scientific views and interpreting students' views from a constructivist perspective." To get started, I share with them a personal example which involves my eldest daughter, Amanda. Five years ago at the end of first grade, Amanda announced at the supper table that she knew why days become longer in summer and shorter in winter. My attention level markedly increased. After a sequence of father's questions and daughter's answers, ten minutes had elapsed, and Amanda had described and defended her theory. According to Amanda, the earth spins faster in winter and slower in summer. In response to several of my questions, I learned from Amanda that: 1) the earth's spin meant its rotation on its axis; 2) she assumed that the earth spins; and 3) she explained the lengthening

and shortening of days in terms of the sun's position relative to her waking up in the morning and going to sleep in the evening. In summer, the sun is already up when she arises and is just setting at her bed time. In winter, the sun is just rising when she awakens and disappears long before her bed time.

The practicing elementary teachers with whom I work generally smile and sometimes chuckle, but they express little surprise at my example, perhaps because they have many more examples of their own. In response, teachers typically tell about their own experiences, and an extensive sharing of students' alternative conceptions occurs. The examples are far too numerous to mention, but they provide ample information for the next discussion.

I ask, "How do you suppose that youngsters come up with these ideas?" A common response from ›chers is that their students learn these ideas from other children. At this point, I focus the discussion on the constructivist notions that were introduced earlier and point out that within a constructivist view, the teacher is not the active transmitter, and the student is not the passive receiver of knowledge. Rather, learners actively build or construct knowledge using their prior knowledge. Given this perspective, I ask, "If the teacher is not the giver of knowledge, then what should the teacher be?" Elementary teachers, particularly those at the primary level, typically respond that youngsters need concrete experiences to learn best. I point out that they are facilitating students' construction of knowledge by setting up learning experiences with concrete, hands-on materials. Moreover, being a facilitator of and guide for their students' construction of knowledge are important roles for teachers.

Emphasizing the importance of prior knowledge and using Amanda as an example, I then point out that if we wish to help students to change their conceptions, then we must facilitate such change. At this juncture, we usually engage in an extensive discussion regarding activities for Amanda that could perhaps help her to reconstruct her personal theory about the lengthening and shortening of days. The discussion extends to other examples of students' alternative conceptions. Out of this discussion, I introduce the Learning Cycle as a guided inquiry instructional model which utilizes hands-on, minds-on activities, is based on the constructivist notions introduced earlier, and is appropriate for helping students change their conceptions. Because other writers (e.g. Staver & Shroyer, 1993) in this volume have discussed the Learning Cycle in great detail, I refer readers to those chapters. Then, I focus the discussion on teachers' roles in utilizing the Learning Cycle to help students change their conceptions. As a result of these discussions, teachers' reflect on their roles in carrying out guided inquiry instruction. Teachers consider, for example, that they should: (1) focus students' interest and curiosity by beginning with concrete activities; (2) ask probing questions to elicit students' responses which reflect students' conceptual understanding; (3) ask students to provide evidence to support their explanations; (4) ask students to examine alternative explanations; and (5) look for evidence in students' explanations that students have modified their thinking. In concluding the Elaboration phase, I usually point out that an axiom of inquiry teaching for

conceptual change calls for teachers to ask lots of questions and to devise other instructional situations, which reveal what students think.

The Evaluation phase is dependent on the length of time that I have with teachers. In a brief workshop, my evaluation is limited to informal means. The extensive interaction that has occurred allows me to assess their knowledge of constructivism and their acceptance or rejection of its basic ideas as I have introduced them. I strongly encourage teachers to design and carry out a segment of instruction using the Learning Cycle. I ask them to seek me out at local and state meetings of science teachers to tell me about their experiences. I also recommend that teachers look into the possibility of using some *Full Option Science System* (Regents, University of California, 1992) or *Science for Life and Living* (BSCS, 1992) activities because these curriculum projects utilize the Learning Cycle.

In graduate level courses, I have teachers do similar kinds of activities, but the Evaluation phase becomes more formal. For example, teachers design and teach Learning Cycle lessons, then debrief these teaching experiences in class. I ask teachers to keep reflective journals. Sometimes I learn of new examples of students' alternative conceptions through teachers' journals. I occasionally ask teachers to write a paper in which they describe their own personal view of knowledge and its acquisition. I make it clear that they do not have to agree with constructivism. Rather, they must reflect and write about their own views. I have learned a great deal from such papers.

A Concluding Thought

Within a constructivist perspective, science is a powerful and disciplined human activity for building knowledge that allows us to explain and predict the natural world. However, constructivists do not conclude that such knowledge corresponds with the structure of the outside world, regardless of its explanatory and predictive power. In teaching teachers to teach science, those of us, and I count myself among them, who have adopted a constructivist epistemology need to honor these fundamental theoretical principles in our own teaching. In this way, I hope to improve my own teaching and the teaching of those teachers with whom I interact.

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Eliciting Preservice Elementary Teachers' Beliefs About Science Teaching and Learning

Sheila M. Jasalavich
Larry E. Schafer

Some of the major topics we address in our elementary science methods courses are hands-on problem solving, sequencing of instruction with particular emphasis on the learning cycle, constructivism, and epistemology. Before we begin our instruction, we find it helpful to ascertain our students' prior beliefs about these different facets of science teaching and learning.

We have struggled to find ways to discover what our students really think about different aspects of science teaching and learning. We have taken our lead on how to elicit people's views from educators such as Osborne and Freyberg (1985). They have used eliciting instances or events to uncover people's views about different science concepts. For example, if a teacher wants to discover fourth grade students' understanding of condensation, the teacher can use the following eliciting event. She places a glass full of water and ice on a table. The glass sits there for a few moments and the children observe as the outside of the glass becomes covered with droplets. The teacher asks the children, "Where did the 'stuff' on the outside of the glass come from?" One student says, "It came through the glass. It's like osmosis or something." Another student says, "I think the water crawls up the side of the glass and goes over the top edge and then drops down on the sides." A third student says, "No, the water on the outside of the glass is coming from the air and not from inside the glass." Immediately following the third student's response, several students shout out, "No way! The only water around is inside the glass so it has to be coming from inside the glass." This teacher has discovered a multitude of ideas her students have about water through the use of a concrete, eliciting event.

Using a concrete, eliciting event is important if the teacher wants to discover the children's views and gain insight about particular ideas that she will need to address during instruction. Without a concrete, eliciting event, children often say nothing because there is no concrete situation to which they can relate or they simply say what they think the teacher wants to hear and attempt to regurgitate a textbook definition word for word. The same is true of preservice and experienced teachers. If you ask them to describe good science teaching, their descriptions will likely include phrases like hands-on, minds-on, cooperative learning, and teacher as facilitator of learning. If you then observe their lesson planning and teaching, however, you often find discrepancies between what they described as good science teaching in a general discussion and the way they plan and teach.

Likewise, when asked to critique science lessons being taught, individuals' remarks about what makes a science lesson good often deviate from the earlier "hands-on bandwagon" that emerged during the general discussion. For example, some teachers who espouse the virtues of hands-on, minds-on problem solving in science outside of a specific context show, in reaction to specific teaching events, that they do not really believe that children can solve problems on their own. Thus, just as we must use concrete, eliciting events to tease out children's ideas and beliefs about scientific phenomena, we must also use concrete, eliciting events to tease out preservice teachers' ideas and beliefs about science teaching and learning.

Why should we tease out preservice teachers' beliefs about science teaching and learning? The answer to this question develops from a constructivist perspective on learning. This perspective operates on the premise that learners do not enter a new learning situation such as a science methods course as blank slates, but enter with ideas and beliefs which directly relate to and often conflict or interfere with the new ideas being presented. Furthermore, there is the premise that unless the learners' "entrance" or "current" ideas and beliefs are addressed during instruction, those ideas and beliefs will not necessarily be changed or replaced by new ideas and beliefs. Learners must have good reasons to change their minds. The old ideas must be seen as inadequate in the face of argument and evidence and the new ideas must be seen as reasonably supported by argument and evidence (Osborne and Freyberg, 1985). If a constructivist approach is to be taken in the education of science teachers, then teachers' views must be revealed and must be addressed either directly through instruction or indirectly through planned experiences. We tease out our preservice teachers' beliefs, therefore, to identify not only what needs to be addressed in instruction, but to raise issues and introduce the topics to be covered in the science methods course.

We have already stated that major topics covered in our methods courses include hands-on problem solving, sequencing of instruction with particular emphasis on the learning cycle, constructivism, and epistemology. More specifically, the methods of science instruction that we address in our courses depend on teachers incorporating the following beliefs into their views of good science teaching.

1. Children are able to figure things out for themselves, solve problems, and create explanations.
2. It is important to continually elicit and address children's views of scientific phenomena throughout instruction.
3. An effective sequence of instruction is to begin with concrete, hands-on experiences and discussion of ideas that emerge from these experiences and then follow with a more formal concept introduction.
4. Learning about relationships is more important than learning information and memorizing terms.

We have developed a set of eliciting events, teaching incidents, that we use to uncover preservice teachers' "initial" beliefs about science teaching and learning. We then use their views to determine the extent to which they subscribe to the four beliefs described above and use the knowledge we acquire to plan meaningful methods instruction.

The eliciting events consist of three pairs of science lessons taught in elementary classrooms. Each pair of lessons describes two different approaches to teaching the same science concept or topic at a particular grade level. We use these teaching incidents as the basis for detailed discussions on what constitutes good science teaching. We encourage our students to compare the lessons, indicate their instructional preferences, and state their reasons for their views. We guide the discussion by asking a series of questions in which we ask for students' views on particular aspects of the science teaching and learning occurring in each lesson.

Eliciting Events

Lego Block Cars Lessons

We use a pair of Lego block cars lessons to elicit preservice elementary teachers' beliefs about problem solving and sequencing of instruction. The first version of the Lego block cars lessons is as follows:

> Jillian gives her second grade students Lego blocks and challenges them to use eight blocks to make a car that's strong and won't fall apart when dropped on the hard floor from a height of six feet. The children work in groups and each group makes a car which the teacher drops. The children see what happens to their car. Jillian asks the children questions to help them see the differences between cars that break into many pieces and cars that break into only a few pieces. Then the children redesign their car to make it stronger. They do this a number of times, testing and rebuilding. Jillian concludes the day's lesson by asking each group to save their strongest car.
>
> The next day Jillian asks the groups to show their strong car and to make some weak cars. She then asks the students to describe what makes a strong car strong and a weak car weak.
>
> The conclusions reached in this lesson are that a car is strong when there are more connections among the parts and a car is weak when there are fewer connections between its parts.

The second version of the Lego block cars lessons is as follows:

> Ursula, a second grade teacher, makes 3 different cars out of Lego blocks. One car is weak (will easily fly apart into many pieces when it hits the hard floor when dropped from 6 feet), one is moderately strong (breaks into 2 or 3 large pieces), and one is strong (does not break apart at all). She drops each kind of car on the floor four times and counts the number of

"broken" pieces. She records ˙ ⁻umber of "broken" pieces under the headings for each kind of car (wea niddle, and strong).

The chart looks like this:

WEAK CAR	MIDDLE CAR	STRONG CAR
3	2	1
4	3	1
3	2	1
5	2	1

She points out to the children that cars are strong when more of the parts are connected to each other. She also explains that cars are weak when there are fewer connections between their parts.

Ursula finishes her lesson in one class session.

Discussion of Lego Block Cars Lessons

After our students have read the two lesson descriptions, we ask them to describe the differences between the two lessons. Then we begin to tease out their beliefs about different aspects of science teaching and learning by asking the following question:

> If you had to teach a Lego block cars lesson to second graders, would you teach the lesson like Jillian or Ursula? Why?

We encourage our students to provide evidence and argument as to why their instructional preference is an effective instructional approach. The students' rationales give us an initial idea of what they believe about science teaching and learning.

We follow up on this open-ended discussion with a series of specific, probing questions. The discussion questions we use to gain a more indepth understanding of our preservice teachers' beliefs about hands-on problem solving and creating explanations are as follows:

a. Can most second graders solve the problem posed by Jillian and can they construct reasonable explanations? What is the basis for your views?
b. Would most of Ursula's second graders be able to build a strong car on their own? Why or why not?

c. Would most of Ursula's second grade students be able to describe why strong cars are strong? Why or why not?

The discussion questions we use to gain a more indepth understanding of our preservice teachers' beliefs about sequencing of instruction are as follows:

a. Is it important for Jillian's second graders to have hands-on experience working with Lego blocks *before* Jillian talks with them about what makes a strong car strong and a weak car weak? Why or why not?
b. If Ursula decided to add a hands-on experience to the lesson next time she teaches it, should Ursula's students work with the Lego blocks building cars *before* her explanation of what makes a strong car strong and a weak car weak or *after* her explanation? Why?

To bring closure to the discussion of this pair of eliciting events, we generate a list of concerns that our students have about using hands-on problems, asking children to create explanations, and sequencing of instruction.

Preservice Elementary Teachers' Responses to the Lego Block Cars Lessons

Many preservice teachers are fairly skeptical about the ability of students to solve hands-on problems such as building strong Lego block cars that won't fall apart when dropped. They explain their skepticism by stating that students will become frustrated if you ask them to figure out hands-on problems on their own. Some of our methods students suggest that children need to be shown what to do and many prefer Ursula's approach of demonstrating how to build and test weak, moderately strong, and strong cars. Some students also suggest that they can't see how children can figure these challenges out because they view themselves as inadequate hands-on problem solvers. There is a range of views, however, within any methods class. Responses range from "impossible" to "maybe children can figure things out on their own."

While many of our preservice teachers believe in the importance of concrete experience, they don't think most children can construct rudimentary explanations of their experiences. In fact, many of our students believe that Jillian's students will not be able to describe why strong cars are strong and weak cars are weak because Jillian didn't tell them why.

Some preservice teachers feel that providing initial hands-on experience prior to formally introducing a concept is important in order to set a meaningful context. These individuals prefer Jillian's lesson. Others suggest that children need more guidance and explanation before an initial hands-on experience in order to reduce the frustration children may experience when attempting to do science. They suggest that Ursula's lesson does just that.

When students are asked to list their concerns about using hands-on problems, asking children to create explanations, and sequencing of instruction, they

make the following statements:

- I'm really concerned about giving children hands-on problems to solve.
- How can you really get kids to solve problems?
- How do you get them to make sense of what is going on and generate explanations?
- How will I ever be able to teach science that way if I've never been taught science that way?
- I'm concerned about giving kids stuff to experiment with before I've thoroughly explained the concept. They won't know what to do.
- Won't they be frustrated and confused?

Next, we ask our students to examine another set of eliciting events.

Heat and Insulators Lessons

We use a pair of heat and insulators lessons to discover preservice elementary teachers' beliefs about eliciting and addressing children's views of scientific phenomena. The first version of the heat and insulators lessons is as follows:

> Steven begins his unit on heat by asking his third grade class, "What is heat and where does it come from?" After hearing that heat is what keeps you warm and that there are different things that make heat (stoves, lights, candles, fires), Steven asks students how they will keep warm when they go out for recess on this cold winter day. Students respond, "By wearing hats, gloves, scarves, and coats."
>
> Steven then takes two identical cups of hot water (at the same temperature), uses a thermometer to show the students that the temperature of the water in both cups is the same (100 degrees) and then wraps one of the cups in a scarf. The students predict that the cup of water which is wrapped up will be warmer than the unwrapped cup after 10 minutes. While 10 minutes pass, the students draw pictures of one way in which heat is important in their everyday life. After 10 minutes is up, a student measures the temperature of water in both cups and finds the water to be warmer in the wrapped cup. Steven explains, "The scarf prevented the heat from being lost from the cup of water. The scarf was an insulator." Steven writes the word "insulator" on the board and defines it as a material that keeps heat from being lost. Steven asks students to think of other examples of insulators. Students respond with a number of examples including "the pink stuff in the walls of our homes" and "the warm clothes that we wear when we go outside in the winter."

The second version of the heat and insulators lessons is as follows:

> Terrence begins his heat unit by showing his third grade class two identical cups of hot water. He uses a thermometer to show the students that the temperature of the water in both cups is the same (150 degrees F) and then wraps one of the cups in a scarf. The students predict that after 10 minutes the cup of water which is wrapped up will be warmer than the unwrapped cup. While waiting for the results, Terrence asks the class why they think the wrapped cup will be warmer. Sue says, "Scarves are hot." Jonathan says, "Scarves and hats make you hotter." Malcolm adds, "If you leave the scarf around the cup of water long enough, it might get to a thousand degrees!" As Terrence listens to his students' explanations, he realizes that a number of children believe the scarf will heat up the water in the wrapped cup and make it even hotter than it started out. Terrence checks his idea by saying, "The ten minutes is just about up. Will the temperature of water in the wrapped cup be higher, lower, or the same as it was 10 minutes ago?" Most students respond, "Higher."
>
> The 10-minute period is up and the students learn that the temperature in the wrapped cup went down 10 degrees and that the temperature in the unwrapped cup went down 30 degrees. A number of students are amazed that the wrapped cup didn't get hotter. Jonathan insists, "The wrapped cup should have gotten hotter. It must not have been wrapped tightly enough. Cold air is getting in!" Most of the class agrees with Jonathan. Christine suggests that a thermometer be wrapped tightly in a scarf so no cold air can get in. Most agree that the scarf will make the temperature go up especially if the scarf and thermometer are left overnight.
>
> The next day, the students are dismayed when they discover that the temperature on the wrapped thermometer is the same as it was yesterday when they wrapped the thermometer. Christine suggests, "Maybe scarves and hats don't make things warmer; they just keep things the same or keep them from cooling off so fast." While a number of students agree with Christine, there are still a number who agree with Jonathan and hold on to the idea that "scarves and hats and other things make things hotter."
>
> In a later lesson, Terrence puts an electric heating pad in a closed cardboard box (a simulated house) and finds the temperature inside the box rises to a certain temperature and just stays there. He then adds what he calls insulating materials (scarves, hats, paper) to the outside of the house and the temperature inside the house rises. By interacting with the students, he and a number of students explain that the house gets warmer because the insulating materials keep the extra heat which is added by the heating pad from getting out. If the pad is turned off, the insulating materials keep the house warm longer but do not make the house warmer. Insulators don't add heat; they just keep heat in or out. Terrence wonders, however, whether Jonathan is finally convinced that insulators don't add heat.

Discussion of Heat and Insulators Lessons

After our students have read the two lesson descriptions, we ask them to describe the differences between the two lessons. Then we begin to tease out their beliefs about different aspects of science teaching and learning by asking the following question:

- If you had to teach a heat and insulators lesson to third graders, would you teach the lesson like Steven or Terrence? Why?

We encourage our students to provide evidence and argument as to why their instructional preference is an effective instructional approach. The students' rationales give us an initial idea of what they believe about science teaching and learning.

We follow up on this open-ended discussion with a series of specific, probing questions. The discussion questions we use to gain a more indepth understanding of our preservice teachers' beliefs about eliciting and addressing children's views of scientific phenomena are as follows:

a. Do you think the children revealed most of what they know about heat (heat keeps things warm and comes from different things) in Steven's opening discussion?
b. How might students have acquired ideas about heat prior to Steven's instruction?
c. Terrence's third grade students had ideas about heat prior to any formal instruction by Terrence. Do most third graders bring ideas to most science lessons? What makes you think that?
d. Should Terrence have continually allowed students to state their views of heat throughout the lesson? Why or why not?
e. Is Terrence's student, Jonathan, a typical student? Will most third graders continue to hold on to their original ideas when shown that their original ideas are incorrect? Why or why not?
f. Would Steven's demonstration and explanation have corrected Jonathan's mistaken ideas? Why or why not?

To bring closure to the discussion of this pair of eliciting events, we generate a list of concerns that our students have about eliciting and addressing children's views of scientific phenomena.

Preservice Elementary Teachers' Responses to the Heat and Insulators Lessons

Some preservice teachers believe children construct and bring lots of ideas to the classroom. Others feel children bring very few ideas to the science classroom and tell us that Terrence's students were an exception to the rule. Many

preservice teachers think that there are instructional disadvantages to continually encouraging children to state their alternative views. They tell us that Terrence's approach reinforces the children's scientifically incorrect ideas. Many preservice teachers highly underestimate the commitment many children have to their alternative views. They see Terrence's student, Jonathan, as an atypical student. Often teachers believe that a clearly presented explanation is sufficient for changing children's views. They suggest that if Terrence had used Steven's demonstration and explanation, Jonathan would have understood heat and insulators.

When students are asked to list their concerns about continually eliciting and addressing children's views of scientific phenomena during instruction, they make the following statements.

- How do you get children to tell you what they really think?
- Isn't it risky to encourage children to continually talk about their scientifically inaccurate ideas?
- What do you do when you discover that children have some scientifically inaccurate ideas?
- How do you get children to change their views to the scientifically accurate one and how do you know when they have really changed their views?

We then present our students with a third set of eliciting events to discover their beliefs about other aspects of science teaching and learning.

Owl Lessons

We use a pair of owl lessons to elicit our students epistemological beliefs concerning the relative importance of acquiring information and understanding relationships. The first version of the owl lessons is as follows:

> Ian teaches fifth grade and has taken part in a new program for teachers which is sponsored by a local wildlife organization. Rather than send wildlife experts into classrooms, this organization educates teachers about various critters which the teacher can take into his or her classroom.
>
> One day Ian takes Charlie, a live, caged barn owl, into his classroom for a lesson. Ian explains that Charlie is not a pet and would not be in the classroom or anywhere in captivity if he was able to fly. Ian tells the class that a long time ago Charlie broke his wing which did not heal properly. Charlie cannot fly to catch his own food and would likely starve if he was allowed to go free. In the wild, Charlie would eat mostly mice, rats, and other small mammals. Ian tells the class that someone once saw a young barn owl eat 9 mice one right after the other but could not swallow the tail of the last mouse. Young owls can eat over 15 mice a day. Barn owls sometimes eat small birds, bats, frogs, and some insects. Charlie is called a barn owl because

this kind of owl sometimes lives in barns or deserted buildings. At other times barn owls live in hollow trees. Barn owls never build nests.

Adult barn owls often live as pairs and become mother and father to between 5 and 15 baby owls each year. It's hard to tell male and female barn owls apart. Males and females are colored alike and often the female is larger. Young barn owls look like their parents. Both the mother and father spend time sitting on the eggs to keep them warm before the hatching. Most of the time the mother sits on the eggs. Unlike many birds, there can be 15 days between the time the first egg is hatched and the last egg is hatched. A fifteen day old owl can be rather large and is usually very hungry. This sometimes poses a threat to a newly natched brother or sister.

Ian asks the students to describe Charlie's face. Some students say that it is in the shape of a heart. Others say that it looks funny, like a monkey. Ian tells the students that sometimes barn owls are called monkey-faced owls. Barn owls are found in a lot of different places—in the east, far west and south. Sometimes barn owls are found in Mexico and South America. Ian says that the average barn owl has a 47-inch wing span, is usually 21 inches long, and has a 7-inch long tail. Ian tells the students that Charlie is smaller than average since he is 18 inches long and has a six inch tail. Since one of Charlie's wings has been broken, it is hard to measure his wing span.

During recess many of the students spend time watching Charlie. After recess, Ian has the students help him make a bulletin board which summarizes all that they have learned about Charlie and barn owls.

The second version of the owl lessons is as follows:

Tyron learns that Julie, one of his fifth grade students, has a stuffed barn owl. Tyron asks Julie to bring in the owl and tell about it. When Julie is finished telling about how her family acquired Hooter, her stuffed barn owl, Tyron begins a lesson about owls. With Hooter in plain view of everyone, Tyron projects a drawing of a chicken on the screen and asks, "How are the owl and chicken alike and how are they different?" The differences are most apparent and the students comments are summarized and listed on the board.

Tyron reviews when he says that an animal usually survives if it can get its food and can avoid becoming food. Most students agree that chickens eat seeds or grain and that Hooter would probably eat mice which are most active at night. Tyron then directs students' attention to Hooter and asks, "What is it about Hooter which might help him find and capture mice?"

To help answer that question, Tyron has prepared a chicken and owl game. One student becomes a chicken and another becomes an owl. Six students volunteer to be mice controllers. The "chicken" gets a blind fold which covers one eye completely and the other eye partially. The partially covered eye represents the small eye of the chicken. When the chicken looks down at the ground with one eye, the other eye on the other side of the head looks up toward the sky. Chickens look for something on the ground with

one small eye. The "chicken" can only grab things with its fingers (front toes). The "chicken" cannot use its thumbs (no back toes). A chicken cannot hear very well so cotton is placed in the "chicken's" ears. The "owl" on the other hand gets no cotton in the ears, no blind fold, and can grab things with fingers (front toes) and the thumb (back toe). The "owl" and "chicken" are taken to an area of the floor which is covered with sheets of wadded up newspaper (fallen leaves). Under the newspaper are hidden mice in the form of balls of socks. The sock balls (mice) are connected to strings which are controlled by students (mice controllers) sitting off to the side of the newspaper area. When the strings are pulled the mice move. Mice are to get to the side without being caught.

The "chicken" and "owl" stand near the newspaper area (forest floor with leaves). They can reach into the area but they cannot sit or stand in the area, nor can they feel for the mice under the newspaper (leaves). They must wait until they see some movement or hear some noise and then make their pounce to grab the mouse.

The room is darkened (it is night time when mice move about) and the game is played. A number of children get to try the various roles. It is clear that owls with good hearing, front and back toes for grasping, and two large eyes are much better suited for finding and catching mice than are chickens.

Tyron concludes the lesson by focusing on Hooter. The big eyes make it easier to see at night. Having both eyes looking forward helps in locating objects. The front and back toes with sharp claws make it easy to grasp and hold on to things. Hooter's sharp, hooked beak can penetrate and hold on to things and tear them apart. Tyron draws a picture of a barn owl and shows how its ears (hidden under the feathers) start above each eye and circle down on the front of the face to the owl's throat. The students see how big ears on a big face make it possible for owls to hear very well. Hooter is well suited for finding and capturing mice at night.

Discussion of Owl Lessons

After our students have read the two lesson descriptions, we ask them to describe the differences between the two lessons. Then we begin to tease out their beliefs about different aspects of science teaching and learning by asking the following question:

- If you had to teach an owl lesson to fifth graders, would you teach the lesson like Ian or Tyron? Why?

We encourage our students to provide evidence and argument as to why their instructional preference is an effective instructional approach. The students' rationales give us an initial idea of what they believe about science teaching and learning.

We follow up on this open-ended discussion with a series of specific, probing questions. The discussion questions we use to gain a more indepth understanding of our preservice teachers' beliefs about learning about relationships and learning information and memorizing terms are as follows:

a. Ian presented lots of interesting factual information about barn owls. Tyron chose to relate a few owl characteristics with how owls locate and capture their food. In doing so, Tyron explains why the owl's characteristics are the way they are. Which kind of knowledge do you value more and prefer to pass along to your students? Why? Which kind of knowledge would you emphasize? Why?

Preservice Elementary Teachers' Responses to the Owl Lessons

Preservice elementary teachers' experience much tension when asked to make instructional decisions concerning whether to emphasize facts or relationships in their science teaching. Some state that it is important to cover the basic facts because that is what children will be tested on. They believe that Ian's students will be better prepared for tests. Others suggest that focusing only on the basic facts turns science into Jeopardy or Trivial Pursuit. These individuals argue that it is better to cover less and take the time to focus on how things are connected or related. These individuals state that while Ian's use of the live owl is great, students will become bored with the long presentation and remember little of it.

Sometimes preservice teachers think that relationships are too difficult for children to understand. They think that Tyron's students won't be able to see the connection between structure and function.

When students are asked to list their concerns about emphasizing information or relationships during science instruction, they make the following statements.

- I'm worried that if I don't cover all the information, my students will do poorly on standardized tests.
- I'm worried that students won't understand the relationship I'm trying to teach.
- How do you teach information in an exciting manner and make it relevant and meaningful?
- How much information is too much?
- How do you clearly illustrate relationships?

At the conclusion of the aforementioned exercise, we use our course syllabi to show students where we will be addressing their beliefs and concerns about hands-on problem solving, sequencing of instruction, eliciting and addressing children's views of scientific phenomena, and their views of the relative importance of learning information and of relationships. We also tell them that we will ask them to reevaluate the three pairs of lessons later in our courses.

Concluding Remarks

Through the use of these eliciting events we have become more aware of the beliefs and concerns that our students bring to our methods classes. We recognize the importance of discovering their beliefs and concerns and we use them to plan effective methods instruction.

We believe that this exercise is the beginning of our instruction. We model the importance of uncovering students' views, demonstrate one method of eliciting students' views, expose our students to some different ways to teach several science concepts, and encourage our students to reflect on what constitutes good science teaching and learning. We encourage our students to state their views and provide reasons for their views. We encourage our students to question and seek solutions through systematic inquiry and discourse. We challenge our students to become reflective practitioners.

References

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Helping Middle School Pre-Service Teachers to Address Students' Alternative Conceptions

Saouma BouJaoude

The notion that students construct their own understandings about how the natural world works is well established in the science education research literature (e.g., Hewson, 1982; Shuell, 1987). Research has also shown that these understandings are common, invariably different from the accepted scientific understandings, and hard to change through traditional instructional methods (Blosser, 1987).

Researchers have identified students' understandings in a variety of science topics and have recommended methods to affect conceptual change (Pope & Gilbert, 1983; Strike & Posner, 1985). For example, Strike and Posner (1985) have suggested the following conditions for the success of conceptual change:

1. There must be some dissatisfaction with the existing concepts.
2. The new concepts must be intelligible.
3. The new concepts must be initially plausible
4. The new concepts must be fruitful.

Major projects translating research regarding students' understandings into practical approaches to teaching have been conducted at the Institute of Research on Teaching, Michigan State University; Leeds University Center for Studies in Science and Mathematics Education, Leeds University, Leeds, England; and Learning in Science Project, University of Waikato, Hamilton, New Zealand among other places.

Besides recommending specific conceptual change strategies, many researchers have suggested ways to incorporate conceptual change teaching strategies and topics related to alternative conceptions research in science teacher preparation programs (e.g., Smith & Anderson, 1984 and researchers at the Center for Studies in Science and Mathematics Education, Leeds, England and at Waikato University, New Zealand). Smith and Anderson (1984), for example, recommended the following elements to be included in pre-service and in-service teacher preparation programs: 1) developing ideas about conceptual change, 2) generic strategies to implement conceptual change activities, 3) knowledge of some common alternative conceptions, 4) skills for adapting curriculum materials to teach for conceptual change, and 5) skills to diagnose and recognize alternative conceptions from students' answers.

While science educators consistently recommend incorporating ideas from research on students' understandings into the teaching-learning process, research on science teachers' classroom practices suggests that most science teachers still subscribe to a dissemination teaching paradigm. Consequently, there is a pressing need to emphasize conceptual change strategies in pre-service teacher preparation courses.

The purpose of this paper is to describe one component of a science education course—called mini-course for the purposes of the discussion in this paper—designed to help middle school teachers incorporate ideas from research on students' understandings and conceptual change in their teaching. This mini-course includes the following components:

1. Using student evaluation and hands-on activities to introduce pre-service middle school teachers to the possibility of the existence of alternative conceptions.
2. Using written responses to a science problem to educate pre-service teachers to detect alternative conceptions.
3. Using questionnaires found in the science education literature to collect alternative conceptions about two science concepts.
4. Training pre-service teachers in analyzing questionnaire responses.
5. Introducing pre-service teachers to teaching methods to help students change their alternative conceptions.
6. Helping pre-service teachers in designing teaching units using conceptual change strategies.

Description of the Mini-Course

During the first session of the mini-course, pre-service teachers respond in writing to several open-ended questions regarding their ideas about evaluation and attribution of students' mistakes. The purpose of this activity is to make the pre-service teachers aware of the fact that traditional evaluation methods do not provide us with sufficient information about students' ideas about the subject matter. Questions such as the following are used to elicit these ideas: 1) Why, in your opinion, do students fail tests?; 2) Please comment on the following statement: all that good teaching requires is "clear, concise, and enthusiastic presentation of new material; 3) What does the statement "my students understood the material I taught today" mean to you?; and 4) Why are tests necessary?

The following excerpts represent typical student-teacher responses on the above questions. These responses show that pre-service teachers think of evaluation as summative, the sole purpose of which is to assess students' acquisition of knowledge presented in class.

PT3 You evaluate students at the end of a unit to find out if they have achieved the instructional objectives at a satisfactory level.

PT4 You evaluate students to find out if you have met the objectives in the lesson plan.

PT8 When I evaluate my students I want to find out if they have achieved the objectives of the unit.

Moreover, the following responses show that pre-service teachers had not thought about the possibility of the existence of alternative conceptions and that they attribute students' failure on tests to lack of ability, lack of effort, or both.

PT1 Students do not do well on tests because they do not study the material.

PT3 Students fail tests because of poor study habits and test taking skills. Also, some students do not (cannot) understand the concepts. Sometimes they understand the concepts but can't exactly tell what the question was asking.

PT6 Students fail tests for many reasons. Often they don't study. Many times they cannot learn the material presented to them.

PT9 They do not study and they do not pay attention in class.

The responses to the open-ended questions are used to stimulate a discussion of other possible causes for performing poorly on tests. At this stage the idea of the existence of students' alternative conceptions is introduced using a demonstration. In this demonstration equal quantities of steel wool are suspended from the arms of a scale so that they are balanced, and the pre-service teachers are asked to predict to what side the balance would tilt if one of the pieces of steel wool was burned. Typically, pre-service teachers predict that the scale would tilt toward the unburned side because "when things are burned they weigh less". Then, when the demonstration is conducted, the balance tilts toward the burned side. The result of the demonstration initiate a discussion about alternative conceptions, their sources, and possible ways to identify them in students. In addition, this demonstration shows pre-service teachers that students' scientifically unacceptable responses could arise from their attempts to make sense of new situations based on their everyday experiences. Finally, this demonstration shows pre-service teachers that evaluating students' responses to oral and written questions in terms of scientific correctness is not sufficient. Rather, there is a need to analyze these responses to get information about their thinking and alternative conceptions. For example, if students responses on a question such as the above one are evaluated for correctness only, the information about the students' alternative conceptions would be missed and the alternative conceptions might continue to exist even after instruction.

The two goals of a second three-hour session are to a) enhance the pre-service teachers' skills in scanning students' written responses and detecting possible alternative conceptions and b) provide them with more evidence for the importance of in-depth analysis of students' responses to identify alternative conceptions.

A technique recommended by Nussbaum (1979) is used to accomplish these goals. The pre-service teachers are asked to read the explanations, one short and one long, of two high school students to a physical phenomenon (Table 1):

Table 1
Students' Explanations Used to Educate Student Teachers to Identify Students' Alternative Conceptions

Students were asked to consider the following demonstration and provide explanations in terms of the particle theory. Sample explanations are given as "Answer A" and "Answer B." Your task is to analyze the answers to identify possible students' alternative conceptions.

The demonstration: In a certain demonstration a flask full of air had a deflated balloon attached to a pipe coming out of the side of a sealed flask (figures are usually provided). As the flask was heated by the flame the balloon inflated. Explain the phenomena using the particle theory.

Student explanations:

Answer A.
There is air in the bottle which fills it and also fills some of the balloon which is not blown up. If someone places the balloon with the molecules of the air above the flame then it becomes hot in the bottle and the air expands. The molecules move from the bottle to the balloon and this makes the balloon blow up (Nussbaum, 1979, P. 263).

Answer B.
There is air in the bottle which fills it and also fills some of the balloon which is not blown up. Scientists discovered that the air which is in the bottle contains very small particles which they also found to be like ball, can move and reach every place in the air of the bottle. Scientist called these particles molecules. If someone places the bottle with the molecules of the air above the flame, then it becomes ho. in the bottle and the air expands and blows up the balloon. This happens because of the law which says that things expand when they are heated and also because when it becomes hot in the bottle then the very tiny molecules tend to go away from the hot place and so they move from the bottle to the balloon and this makes it blown up. If someone would like to see what would happen if the bottle were cooled down, he would find that the balloon would shrink because of the law which says that things shrink when they are cooled. But with water it does not happen so since when water is cooled below 4° then, amazingly enough, it would expand. This is what they call the anomaly of water (Nussbaum, 1979, P. 263).

Pre-service teachers are asked to take two minutes to read each response and provide a numerical and a short written evaluation of each of them (two minutes are used to simulate the approximate time teachers have to correct similar questions). After the two minutes pass, the pre-service teachers' evaluations are tabulated on the board. The tabulated results illustrate the variety of the teachers' evaluations. Typically, pre-service teachers give grades ranging from 4 out of 10 to 10 out 10 for each question. The short written evaluations range from poor to excellent. The discussion that follows demonstrates the need to read and evaluate students' responses more carefully, not just to give a grade, but also to detect alternative conceptions, even under the time constraints that a teacher faces during grading.

The pre-service teachers are then asked to work in small groups to identify the alternative conceptions that exist in the two responses. Moreover, they are asked to discuss the possible sources of these alternative conceptions. A discussion follows this exercise during which the identified alternative conceptions and their possible sources are discussed. In addition, the differences between mistakes and alternative conceptions and the existence of alternative conceptions in different science topics are discussed.

Finally, different techniques to identify students' alternative conceptions are discussed including interviews and questionnaires. The two interview techniques discussed are the Interview-About-Events and the Interview-About-Instances as presented by Osborne and Freyberg (1985). In addition, pre-service teachers are introduced to the methodology used to design questionnaires to identify alternative conceptions recommended by Osborne and Freyberg (1985).

As an assignment, each of the pre-service teachers is required to administer one of two questionnaires designed to collect students' alternative conceptions. The first questionnaire is the "Misunderstandings Test" that surveys students' understandings about the concept of burning described in BouJaoude (1992). This questionnaire contains 13 two-tier type questions (see Peterson, Treagust & Garnett, 1986, for a description of two-tier type questions). The first part of the question is multiple choice while the second part asks the students to explain their choice in the first part. The second questionnaire is "A survey of students' ideas about force" (Schollum, Hill, & Osborne, 1981). This questionnaire contains 10 multiple choice questions. Questionnaires rather than interviews are used by the pre-service teachers to collect students' alternative conceptions because of: time limitations, the difficulty of training pre-service teachers to conduct interviews in the time provided, and the practicality of using questionnaires to collect alternative conceptions in real classroom situations.

The two questionnaires are administered to students at different grade levels (grade 8, 10, 11, and first year college levels). There are two reasons for collecting students' alternative conceptions at the middle school, high school, and university levels. First, this exercise demonstrates to the student teachers that alternative conceptions continue to exist even after "successful performance" in formal science instruction and that there is a need to address these alternative conceptions as early as possible. Second, this exercise shows the student teachers that students

at different cognitive levels continue to have alternative conceptions and this phenomenon is not restricted to concrete operational students. In addition, a few pre-service teachers are asked to analyze responses of Grade 10 Lebanese students on the Misunderstandings Test to show them that alternative conceptions are not necessarily culturally specific.

During a third three-hour session the survey results on the multiple-choice part of the Misunderstandings Test are tabulated on the board (Table 2).

The tabulated results demonstrate to the pre-service teachers that students at different educational levels and in different cultures have similar alternative conceptions and that these alternative conceptions persist even after students have studied the subject matter covered by the questionnaires. In the discussion that follows, the pre-service teachers are asked to describe the characteristics of students' alternative conceptions using the example of burning as a stimulus. Typical ideas that come out of the discussion include the following:

1. Students' explanations of science events are driven mostly by their observations of the visible physical changes.
2. Students attempt to use "big scientific words" to mask their inability to provide scientific explanations.
3. Most of the alternative conceptions may be genuine attempts to explain observations.

At this stage the pre-service teachers are introduced to several strategies to address students' alternative conceptions in the science classroom. The major strategy is the one recommended by the Leeds University Center for Studies in Science and Mathematics Education (1987). This strategy is designed to: a) elicit students' prior knowledge; b) provide students with experiences to encourage them to extend, develop, or change their ideas; c) provide students with opportunities to try their ideas in familiar and unfamiliar situations, and d) provide students with opportunities to reflect upon their ideas and how these ideas change. Then, the course instructor demonstrates how the four .. ps listed above can be used to design a unit on burning using the alternative conceptions identified by the pre-service teachers. This unit includes a survey to identify students' alternative conceptions about burning (to elicit students ideas), hands-on activities to address each of the identified alternative conceptions, and activities to extend students' ideas into beyond the classroom. The worksheets accompanying the activities in the unit require students to explain specific events and reflect, individually or in groups, on the explanations and results of activities. The emphasis during this part of the mini-course is on showing pre-service teachers that addressing students' alternative conceptions requires the use of carefully planned activities that help students to think through their own alternative conceptions and construct their own scientific explanations.

Additionally, the pre-service teachers are provided with opportunities to inspect and discuss instructional materials designed to address students' alternative conceptions (e.g., Approaches to Teaching the Particulate Theory of Matter

Table 2

Students' Responses on Three Items of the Misunderstandings Test Collected by the Student teachers

Question #1:

Consider what some people say about wax when a candle burns. In your view which is the best statement about wax?

a. The wax is burned in the candle flame.
b. The wax is not burned up; it holds up the wick as the wick burns.
c. The wax is not burned up; it melts and stops the wick from burning too fast.

Grade Level Responses to Question #1:

	G8 USA	G10 USA	G10 Lebanon	G11 USA	College (1)
a:	11%	10%	30%	10%	22%
b.	11%	15%	10%	15%	0%
c.	78%	75%	60%	75%	78%

Question #2:

Equal quantities of steel wool are suspended from the arms of a scale so that they are balanced. The steel wool on side A is exposed to a flame for a long period. What happens to the scale after heating?

a. It tilts down on side A.
b. It tilts down on side B.
c. It stays the same.

Grade Level Responses to Question #2:

	G8 USA	G10 USA	G10 Lebanon	G11 USA	College (1)
a.	19%	15%	5%	5%	11%
b.	75%	85%	52%	80%	72%
c.	6%	0%	43%	15%	17%

Question #3:

Several matches were suspended inside a tightly closed flask. The mass of the flask was then measured. When the glass was heated, the matches caught fire and burned. The flask was then allowed to cool. The mass of the flask after cooling will be:

a. More.
b. Less.
c. The same.

Grade Level Responses to Question #3:

	G8 USA	G10 USA	G10 Lebanon	G11 USA	College (1)
a.	53%	26%	22%	17%	15%
b.	27%	32%	47%	33%	35%
c.	20%	42%	31%	50%	50%

(1987) produced by Leeds University Center for Studies in Science and Mathematics Education; Burning: a Resource Unit for teachers, (Schollum, 1982) produced by the Learning in Science Project in New Zealand; and Food for plants: Teachers' Guide (Roth, 1985) produced by the Institute of Research on Teaching at Michigan State University.

While the major method to address students' alternative conceptions and affect conceptual change discussed in class is the one described above, other strategies, such as using the history of science, discrepant events, and analogies to correct alternative conceptions are introduced and discussed.

During the fourth three-hour session, the pre-service teachers are introduced to the psychological and philosophical terms used in research on students' ideas. Terms such as constructivist and transfer view of learning, alternative theories, naive theories, children's science, and commonsense ideas are introduced and discussed at this stage. Also, the philosophical and psychological reasons for using the different terms are discussed. Furthermore, the role of the teacher, the role the student, the state of mind of the student, the nature of learning, and the nature of knowledge in a constructivist and transfer view of learning, and the implications on curriculum and teaching of using a constructivist view of learning are discussed. At the end of this session, pre-service teachers are required to design instructional units to correct students' alternative conceptions using the recommendations and strategies that are discussed in class and students' alternative conceptions about different science topics identified in the literature.

During the last session of the mini-course the pre-service teachers are asked to respond to the same questions administered at the beginning of the mini-course to gauge the change in their conceptions about evaluation. The following excerpts illustrate that some pre-service teachers start thinking about evaluation as an integral component of the teaching process. What is more important, they start attributing student failure, in part, to persistence of incorrect prior knowledge or the lack of sensitivity of teachers to the existence of alternative conceptions:

PT6 There are many different techniques that can be part of the presentation of new material. It is necessary to understand what prior knowledge, correct or incorrect, students have before introducing new material. Students might not do well later because their prior knowledge was not changed in teaching.

PT9 It seems that students build "new knowledge" over old "wrong knowledge." Just as little children try to reason things out, so do old children. If it works, it sticks with them whether it is true or not. Students sometimes do not do well on a test because their old, "wrong knowledge" sticks with them ... Material has to be taught in a way that makes sense to the students; otherwise the old knowledge does not change. Also, a teacher has to evaluate accurately to know what the student really knows ... when students interact (ask questions and answer your questions) you get a feel for their understanding of the material.

Discussion

This paper described a mini-course designed to help middle school pre-service science teachers identify and address students' science alternative conceptions. There is some evidence to suggest that the pre-service teachers participating in this mini-course become sensitive to issues related to alternative conceptions and start thinking of different ways to address them. The course starts by uncovering student teachers' conceptions about evaluation, because it is through evaluation that teachers may discover that their students have alternative conceptions. To reinforce this idea, pre-service teachers use questionnaires to identify alternative conceptions. When the pre-service teachers are convinced of the existence of alternative conceptions and of the persistence of these conceptions even after formal instruction, they are introduced through discussion to a variety of methods to address these alternative conceptions using a variety of methods. Finally, the theoretical framework on which alternative conceptions research is based is discussed. Thus, the student teachers, for the most part, are convinced at the end of the mini-course that evaluation is not simply evaluating students' responses in terms of scientific correctness. Rather, they now think that for learning to take place students' answers should scrutinized for the existence of alternative conceptions and that teaching methods should be adapted to this reality.

A number of pre-service teachers taking the mini-course get the opportunity to teach the units they design during their student teaching. Most of these pre-service teachers report that students enjoy this type of t ıching. However, they have provided the following barriers which need to be removed before conceptual change strategies become the preferred method of teaching. These barriers include:

1. Pressure to covcı all topics in the curriculum, especially at upper grade levels.
2. Difficulty of using conceptual change strategies with large, mixed-ability classes.
3. Scarcity of instructional materials to support teachers who choose to use conceptual change strategies in their classrooms.
4. Lack of continuity between one class and another in the use of this approach. Several pre-service teachers were faced with resistance from host teachers who did not value student-centered teaching.
5. Existing beliefs about the role of teachers and students in the classroom. Several pre-service teachers reported that their host teachers believed that the role of the teacher is to provide information while the role of the students is to learn this information. Any teaching approach that contradicted this belief was considered detrimental to student success according to those teachers.

The above perceived constraints may become real when the pre-service teachers start teaching their own students in their own classrooms. Consequently,

to implement these methods they will need the support of their school community. More importantly there needs to be a change in the definition of what it means to be a good teacher. For conceptual change strategies to become the norm and not the exception, teaching should be viewed as helping students to construct their own meaning of science experiences rather than encouraging them to passively absorb information presented by teachers.

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Increasing Student Curiosity, Persistence, and Critical Thinking During Science Activities

John B. Bath

During the past few semesters, I have become increasingly frustrated with my inability to develop in elementary science methods students the traits of curiosity, persistence, and critical thinking. I recognize, that as young children, these students may have been naturally curious and sought to describe and sort the diverse materials they discovered during explorations of their world. As young children, they may have been curious and persistent and developed critical thinking skills while gaining an understanding of their surroundings. I also recognize that effective teachers of elementary science enable students to maintain or provide opportunities to acquire these traits while extending their first-hand knowledge of the world. From my observations, however, many (if not most) elementary science methods students have lost these traits or are unable or unwilling to display them. To become effective elementary teachers of science, they must regain the traits of curiosity, persistence, and critical thinking and display them.

Blaming students for these short-comings is easy. They come to the university, lacking knowledge of science content and having little or no knowledge of science process skills. Many students dislike science and have grown used to sitting in class as passive learners. In spite of these student short-comings, an effective instructor of elementary science methods instills curiosity, persistence, and critical thinking.

Background

I believe in active learning, following the constructivist model (Yager, 1991). I involve students in minds-on and hands-on activities at various levels of inquiry (Table 1). During the first few class sessions of my elementary science methods course, students participate in activities representative of the lower inquiry levels, where they receive a problem, procedure, and solution or just the problem and the procedure, but not the correct solution. In subsequent sessions, they participate in activities representative of the higher levels of inquiry, receiving a problem, but no set procedure or solution.

Table 1
Levels of Science Inquiry

	Experimental Parts		
Level of Inquiry	Problem	Procedure	Solution
Level 3 (High)	Determined by student	Determined by student	Determined by student
Level 2 (Moderate)	Given by by text or teacher	Determined by student	Determined by student
Level 1 (Low)	Given by text or teacher	Given by text or teacher	Given by text or student
Level 0 (None)	Given by text or teacher	Given by text or teacher	Given by text or teacher

My frustration has been with students apparent lack of curiosity, persistence, and critical thinking during activities regardless of the level of inquiry. During inquiry level 0 activities, students have read the problem, followed directions, and verified a solution. Generally, students have followed directions and have completed these activities with few difficulties. They stopped their activity, however, with no further interest, when they obtained the given solution. Those not obtaining the given solution also stopped their activity, apparently unwilling or unable to determine what went wrong.

When no correct solution was given (inquiry level 1), students became frustrated when they realized I was unlikely to verify their solutions, but asked a series of questions in an attempt to determine their confidence in their solution and the procedures used to obtain that solution. Most students checked their solution with other students. They ceased activity if their solution agreed with other students. They also ceased activity if their solution did not agree.

Activities at inquiry levels 2 and 3 have increased their frustration and mine. Students were free to design their own procedures at level 2 and to develop their own problems at level 3. They displayed a lack of curiosity, persistence, and critical thinking by completing the minimum, most obvious problem, and they made no attempt to confirm solutions or check inconsistencies in the data they obtained.

I believe effective teachers of elementary science must display the traits of curiosity, persistence, and critical thinking if they are to maintain or increase these traits in their elementary students. CoRT (Cognitive Research Trust), a program created by Edward deBono (1985), is used by many businesses to improve employee thinking skills. The program uses direct teaching of lower and higher level tools that enhance the ability of people to think critically. I now use four lower-level CoRT tools during science inquiry activities in an effort to increase student curiosity, persistence, and critical thinking.

Purpose

The purpose of this paper is to describe my attempt to use four CoRT tools (analyze, consider all factors, other people's view, and select) and one science process skill (operationally define) to increase the curiosity, persistence, and critical thinking skills of university students during elementary science inquiry activities (Costa, 1976 and deBono, 1985). I teach and implement the CoRT tools with a pendulum activity. I expect students to incorporate the CoRT tools in a future lesson plan and teach this lesson during field experience.

Modeling the CoRT Tools

I begin CoRT instruction by modeling each of the four tools while investigating a wooden pencil. The first step is to *analyze* the pencil by identifying the parts. A pencil has an eraser, a wooden six sided 'cylinder', a solid graphite cylinder embedded in the wood, and a brass band to hold the eraser to the wood.

Step two is to *consider all factors* that can affect each part of the pencil. I list the following: Make the eraser smaller or larger. Remove the eraser. Make the diameter of the pencil smaller or larger. Change the length of the pencil. Change the color. Vary the diameter of the graphite cylinder. Glue the eraser on the wood to eliminate the brass band. Use other materials besides wood.

The third step is to *select* the factors of personal interest. I am interested in how the diameter of a pencil affects the writing of primary children.

The fourth step is to *operationally define* the selected variables. I decide to use three diameters of pencils, 5 cm, 10 cm, and 15 cm. Each pencil will be 20 cm long. I will judge the manuscript writing of each child using a standard written paragraph and ten-point reference writing scale.

The fifth and last step is to use *other people's views*. Although people view the same object, each sees it differently. In *other people's views*, there is an attempt to observe the object as another person might and talk with other people to obtain more information. For the pencil, I thought the following people might have interesting points of view: a 6-year-old student, pencil manufacturer, pencil salesperson, pencil advertiser, a teacher who normally writes with a pen, and a parent who uses a mechanical pencil. I attempt to think of pencils from each of these people's points of view. Seeking each of these people for their actual point of view is probably better.

I use *other people's views* as the last step to elaborate and to extend the investigation beyond the classroom activity. Other people's views might be used as step three to gain different perspectives before selecting a problem of interest.

Implementing the CoRT tools

I engaged groups of students by challenging them to use a string and set of washers to make a pendulum with the longest possible period. After this initial engagement, they began further investigation of the pendulum using the CoRT

tools. During the pre-activity discussion, we followed the first four steps outlined above. The students began the class investigation of pendulums after step four. Step five is part of the post activity discussion.

Step 1: Analyze

Students analyzed the pendulum by identifying its parts. Students identified the following five parts of a pendulum: (a) the stand or support, (b) how the cord is attached to stand, (c) the cord, (d) how the cord is attached to the bob, and (e) the bob (Table 2). They soon added more parts called "other factors".

Step 2: Consider All Factors

Students considered all the factors that might affect each part of the pendulum. They identified many factors for use as independent and dependent variables and recognized the need to control other factors during their inquiry (Table 2).

Step 3: Select

Students selected the factors in which they had a personal interest. They identified many factors from which to choose after applying the CoRT tools of analyze and consider all factors. Many students displayed interest in more than one variable and decided to conduct further investigations. When students selected independent and dependent variables, they seemed to understand the need to control many of the listed factors. With the use of the CoRT tools, students explored many variables other than mass and length, understood the need to look at factors for controls, and selected one of two variables to explore during class. Many continued their explorations outside class.

Step 4: Operationally Define

Students knew how to operationally define variables from previous instruction. They selected the variables of interest and explored and operationally defined each. Their operational definitions for the length of a pendulum generally included 50, 60, and 70 centimeters. Many decided to verify their conclusions by further investigating pendulums with lengths of 100 cm and 200 cm.

After completing steps one through four, students conducted their investigations and collected data. Near the end of the class session, when most groups had collected substantial amounts of data, I moved students into the last step to elaborate and extend their investigation of pendulums using other people's view.

Step 5: Other Peoples Views

Students considered the pendulum from *other people's views*. This activity proved very rewarding since it seemed to motivate students to pursue knowledge

Table 2
Analyzing and Considering All Factors of a Pendulum

Part of Pendulum	Factors that may affect this part
1. Stand	a. height above the floor or ground b. strength of bar—rigid or flexible c. movable—in a direction of swing d. movable—at right angles to swing
2. How cord is attached to bar	a. through hole in cross bar b. how tied to cross bar—tightly or loosely c. tied to ring place around cross bar
3. Cord	a. type of material—string, wire, rope b. color—red, white, blue, green, multi-colored c. twisted—twisted or non-twisted strands d. length—vary length of cord e. thickness—vary thickness of cord f. knots—tie various number of knots in cord g. elastic—use rubber to spring instead of cord h. wet/dry—compare wet cord with dry cord i. use more than 1 cord j. use a tube instead of a cord k. use a solid bar instead of cord
4. How cord is attached to bob	a. tight or loose b. effect of length of pendulum
5. Bob	a. weight—vary the size b. size—vary the size c. material—make bob of different materials d. use a hollow or solid bob e. use more than 1 bob f. shape—vary shape g. ice—what happens as bob melts h. use washer—vary diameter of hole i. use bar—vary length j. color—vary color k. use ball containing liquid
6. Other Factors	a. how far to pull bob before release b. how will bob be released c. put pendulum under water d. put pendulum in a gas e. vary path of pendulum, ellipse, straight line

about pendulums outside class. Students considered the following: (a) clock makers, (b) a wrecking ball, (c) hypnotist, (d) a maker and user of swings, (e) an instrument of torture (as in The Pit and the Pendulum), (f) a user of ear rings, (g) a metronome, and (h) a pendulum found in museums to demonstrate the earth's rotation. They listed questions for each person using the pendulum (Tables 3 – 7). They also decided to form groups to further explore topics generated during the *other people's views* activity.

Results

Table 3
The Clock Maker's Point of View

Part of a pendulum:	Factors that may affect this part:
1. Stand	• Does the height of the clock make a difference? (Grandfather versus mantle clock)
2. How cord is attached to bar	• How is cord attached to the clock works? • How is noise kept to a minimum?
3. Cord	• What type of material makes up the cord?
4. How cord is attached to bob	• Does the attachment affect the length?
5. Bob	• Is the bob decorative or functional? • Does the mass have any effect? • Does the bob affect the length of the pendulum? • Does the shape have any effect?
6. Other	• How is the precision of time kept? • What is the best time of period? • How are repairs made easily? • What do the chain and weights do?

Table 4
The Wrecking Ball Point of View

Part of pendulum:	Factors that may affect this part:
1. Stand	• What is the best height (for different size buildings)? • How sturdy does the stand have to be? • Should the stand move? In what direction?
2. Cord	• What is the best length? • What material is best?
3. Bob	• What is the best size? • What is the best shape?
4. Other	• What is the best speed? • What is best distance of swing?

Table 5
The Hypnotist Point of View

Part of a pendulum:	Factors that may affect this part:
1. Stand	• What is the best position of hand (above, at, or below eye level)?
2. Cord	• What is the best length? • Should the cord be decorative or plain?
3. Bob	• What is the best size? • Should the bob be decorative or plain? • What is the best shape?
4. Other	• What is the best speed? • What is the distance of swing?

Table 6
The Swing Point of View

1. Stand	• What is the best height? • Does the stand have to be sturdy?
2. How cord is	• What are ways to reduce friction?
3. Cord	• What is the best length? • What are the best materials (chain or rope)?
4. Bob	• What is the best material (tire, board, or strap)? • What is the best size? • What is the best shape? • Does the person's size and weight matter?
5. Other	• How does the pumping action of person affect the swing?

Table 7
The Torturer's Point of View—as in The Pit and the Pendulum

1. Stand	• Does the height intimidate? • Does the mass intdimidate? • Does it have to be sturdy?
2. Cord	• Does length matter? • Does type of material intimidate?
3. Bob	• Does shape of blade matter? • Does mass of blade matter?
4. Other	• Does speed of bob matter?

While there are many different indicators of curiosity, persistence, and critical thinking, I have chosen the following indicators to define these terms. Students display curiosity by (a) speaking and listening to others during the pre-activity discussion; (b) actively manipulating materials and verbally interacting with others during the activity; (c) exploring more than one variable; and (d) explaining findings, asking questions, and generally participating in the post activity discussion.

Persistence occurs when students (a) verify or confirm their findings by collecting more data, (b) repeat portions of an experiment to check inconsistencies in the data, (c) repeat an experiment to correct errors, (d) attend to details during the experiment, and (e) complete experiments during class or at home.

Students display critical thinking when they (a) look for patterns in the data they collected, (b) make predictions based upon the data, (c) recognize errors in their data, (d) identify the sources of those errors, and (e) make changes in their experimental procedures to correct errors.

Curiosity

Students using the CoRT tools displayed curiosity by actively participating during the pre-activity discussion, during the activity, and during the post activity discussion. All students seemed actively involved and remained on task during the entire class session. Many explored more than one variable and seemed genuinely interested in exploring each variable. Most explained their investigations and findings and asked questions about other student investigations. The post activity discussion was especially lively as students interacted with each other and discussed further investigations using *other people's views*.

Students with CoRT training generated many ideas that previous students, without the training, never mentioned during class discussions. They asked questions such as: (a) If the bob of the pendulum were a block of ice, what affect would the melting of the ice have on the period? (b) How are the playground toys which children ride at McDonalds (play animal perched on a large spring) like pendulums? (c) Are vibrating objects, like the strings of musical instruments, pendulums?

Previous students, without CoRT training, seldom displayed a high level of curiosity. They usually explored one variable and stopped. Few students ever attempted to design and carry out another activity to find out more about pendulums. Although most students in previous course sections had been activity engaged in the pendulum inquiry, some sat passively and watched their classmates complete the activity.

Persistence

Students with CoRT training persisted by verifying and confirming their findings. They collected considerable data. Many repeated portions of an experiment to check inconsistencies in the data, corrected errors, and attended to

details during their experiments. Many students completed experiments during class and further explored pendulums at home. Those who did not complete an activity during class time, completed their investigations at home.

Previous students, with no CoRT training, displayed little persistence by comparison. In the past, many students thought that the length of the string affected the period of the pendulum, but the data they obtained was inconsistent. Some students determined that mass affected the period, while others determined that mass did not affect the period. Only a few groups of students had ever attempted to verify their data, repeat portions of their procedure, or repeat an experiment to correct errors. Students who did not finish work in class seldom completed the activity at home.

Critical Thinking

Critical thinking increased among students who had CoRT training when they found patterns in the data they collected and made predictions based upon the data. They recognized errors, identified the sources of those errors, and made changes in their experimental procedures to correct errors. Most recognized the need for control variables and many identified those variables that needed control.

Previous students, without CoRT training, seldom displayed these marks of critical thinking. Many groups of students have tied a weight on one end of a string and wrapped the other end of the string around a pencil. The pencil was held by one student during the experiment. I have always been amazed that few students ever seemed to notice that as the holder began to sway with the pendulum, the period began to change. In the past, many students supported their pendulums from a table or from the wall. Again, few seem to have noticed the string rubbing against the table or wall and its effect on the period. I have had groups of students obtain data full of inconsistencies that was evident in their tables and graphs. They seemed unimpressed.

Lesson Plans

Every student implemented the CoRT tools as part of a lesson they taught to pupils in a local elementary school. After teaching their lessons, students returned with similar stories of success. They reported the CoRT tools were easy to teach to elementary pupils and were easy to apply to other subject areas as well. *Other people's views* was a favorite since it seemed to allow for the most creativity. Two students used other people's view for their language arts methods course. They showed elementary pupils a newspaper article about manatees being hit by boat propellers and the need for boat speed limits. They instructed their pupils to rewrite the article from *other people's views*. Pupils rewrote the article as boat owners, water skiers, boat salespeople, people who live along the water who do not own boats, people who live along the water who prefer non powered boats, and as a mother manatee.

Conclusions

Although I have conducted no scientific study, it appears to me that the CoRT tools can increase curiosity, persistence, and critical thinking of students during science investigations. Modeling the tools takes only a few minutes of class time and students quickly learn how to apply the tools to scientific investigations. I am not sure, however, that the results are due to the CoRT tools or to increased structure of the activity. Since I tend to provide students well structured activities, within the guidelines of the levels of inquiry, I tend to think the CoRT tools help. The results were so dramatic, that I plan to continue to use the CoRT tools in my elementary science methods course. More rigorous scientific research would help to determine the effect of the CoRT tools on curiosity, persistence, and critical thinking.

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Having Elementary Preservice Teachers Experience Science as a Way of Knowing: Gaining a Voice, Losing an Attitude.

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It is an interesting dilemma. When the science education faculty at our college surveyed our students about their past histories and present attitudes concerning science, a number of seemingly contradictory outcomes appeared. More than 95% of the students in our elementary and early childhood methods classes listed science as "one of their two least favorite subjects in school," or as their "least favorite" subject in school.These same students, however, believed it is important to teach science to their students once they begin teaching. Hence a dilemma was soon uncovered in the first day's class discussion: If I don't like a subject and am not excited about it, how can I get my students interested and enthused?

A further perusal of these surveys uncovered some other contradictions. Most of the students in the classes (96% women) had taken at least three years of high school science and two additional lab and lecture classes of college science. Yet these same students not only disliked science, but were uncomfortable with the subject. They felt less prepared than in other subject areas and were afraid to teach it.

We quickly decided what we had here was an *attitude* problem. Before we could try to approach the pedagogical skills and knowledge that are usually the core of our science methods courses, we must address the issue of changing attitudes about science and science teaching. Better yet, activities that would induce this positive attitude change needed to be imbedded in the pedagogically oriented activities.

The surveys, conducted both through interviews done by an ethnographic researcher and by paper and pencil response, provided some additional insights into the nature of the problem that allowed us to redesign both our methods classes and our required science courses. None of the students had experienced hands-on inquiry science on a regular basis at any level of schooling. A vast majority saw science teaching as the distribution of factual information. Scientists were seen as an elite core of mostly older cantankerous men by more than 90% of the preservice students. Less than 2% said they had ever met a scientist and none of them had any idea of precisely what a scientist would do during a normal work day, including the handful who personally knew scientists. Likewise, people who taught science were a "strange breed," with a few exceptions, and the students in the methods classes could not picture themselves "doing to their students what was done to them in science class."

The assignments that we were to give the students in the methods courses, as well as the activities we needed to engage them in during class, needed to be designed to counteract these negative attitudes that our students had acquired through their years of schooling. The assignments and activities needed to be diverse in nature, for the attitudes covered a large territory. However, once we began to create individual experiences for the students, we realized that all of them led back to two related questions: What is science and consequently, what are we trying to teach our students? and How are scientific understandings, attitudes, and skills best learned by children and adults of all genders, ethnic groups, and races?

Students had never *done* any science as part of their science course work, had never met scientists and talked to them about what they did, and because most were women, had been kept technologically illiterate by our society. What follows is a set of assignments and activities that attempts to address these issues. Preliminary feedback since we have instituted these interventions in the science methods courses, in conjunction with two *constructivist science courses* taught by science faculty, show some reasonable change in these attitudes. Once the students' attitudes were addressed, the students' negative experiences validated, and a new vision of science and the pedagogy related to it accepted, then the knowledge and skills that seemed so difficult to "teach" in previous methods courses became attainable for these students.

The methods course gives students the opportunity to explore science as a way of knowing the world and as a tool for problem solving. This is in stark contrast to what they had previously experienced. They are asked to go along with us and seriously attempt what we ask them to do. The students are told that much of what had been done with them in the name of science in their school experiences had very little to do with what science really is and how it can best be learned. Therefore, they will be actively engaged in "doing" science as well as talking about it and reading about it. Much of what we hope children can understand and appreciate about science, they will be doing in the methods class. We talk about "sciencing" rather than studying science. That is, we encourage students to be scientists and design and conduct investigations that address problems associated with how the natural world works. Science becomes a collaborative and participatory experience. It is much more about *process* than it is about *facts*. They, the preservice students, need to be prepared to join in and explore.

Effective science teaching involves a commitment to personal competence. The course facilitates that goal by providing *windows* through which the students can explore the most effective teaching practices in science, and *mirrors* which will reflect and validate their own experiences with science. Since we know that teachers play a major role in infecting their students with their phobias or passions toward science, it is vital that those who teach young children overcome their own anxieties about school science and see how inclusive appropriate science can be.

Each week the preservice students have the opportunity to "science" in the lab or on field trips. They begin to create appropriate science activities that will

allow them to become the catalyst for having elementary or early childhood students excited and energized about doing their own investigations. They visit the "working world" of science and attempt the beginnings of confronting their own dealings with machines and technology. In this course science is never done separately from the rest of life—not separate from other subject areas, not separate from the students' lives in their neighborhoods and homes. It reflects how a school day should be—SEAMLESS.

Part I - Looking Inward

Although this reflection or *looking inwards* is interspersed throughout the whole course, we introduce science teaching by asking students to examine their past history in school science through their science autobiography and other assignments. They also become familiar with science as process and their role as an active learner in this course. They work in groups and individually as they observe and participate in science and technology tasks and experience a variety of "sciencing" experiences in our classroom. They have the opportunity to understand what research tells us works best for children in science as they reflect upon the children they once were. They reflect upon the curiosity that many of them have had "knocked out of them" by our school systems. As Neil Postman says, "We enter school as question marks and leave as periods." Many of the students find themselves reflected in this quotation as they write about their school science experiences.

These students are asked to consider the attributes of a scientifically literate person and read articles and write on this topic. Gender bias in early childhood science teaching is addressed with an examination of the current research and strategies for improvement. The students write one another and themselves about their feelings about 'sciencing'. This genesis period of the course, although emphasizing the *mirrors* that allow the students to clearly see their history as science learners, gives perspective to these personal experiences by providing a few *windows*. These *windows*, the written words of the research articles they read on gender bias or the spoken words of their peers as they engage in "sciencing," provide a vision for how positive science could be for themselves, and their own future students. The interrelationship in this *mirrors and windows* metaphor is an underlying structure for the methods class. "If the student is understood as occupying a dwelling of self, education needs to enable the student to look *through* window frames in order to see the realities of others and *into* mirrors in order to see her/his own reality reflected" (Style, 1988, p. 7). Knowledge of both types of framing are necessary in order for the student to understand that their past history with science instruction is not indicative of the job they can do as a teacher.

Assignments and Activities (The part written in italics is as it appears in the course syllabus)

Science autobiography

This is your initial writing assignment. You will be asked to reflect upon your own school science experiences from your earliest memory to the present. What was it like for you? Did you like it, hate it, or not have much of it? What about experiences outside of school that might have been science; write of them also. Be as candid as you possibly can and remember that we learn forwards and backwards at the same time.

This assignment is given the first day of class to be done as homework. As noted earlier, 96% of the students in our early childhood and elementary methods classes are women. Most of these women have had bad experiences with science since most of their learning in science has been the memorization of countless, unrelated terms. They dislike science, are scared of it, and therefore do not intend to teach much science in their classrooms.

Since most of what good teachers are expected to do with science in an elementary classroom is completely unrelated to their past history as formal science learners, it is useful for them to recognize what was done to them and to compare that to the constructivist science activities they are about to experience in the methods course. If these students are going to take a positive approach to science teaching in their future classrooms, then they must clearly see the distinction between how they experienced science learning and how it negatively affected them and how they, and the children they work with who are similar to them, react to more appropriate "sciencing." They are asked to write about their school history as a science learner—especially in elementary school. They should include any examples of specific incidents that exemplify their remembrances. In addition, they are asked to talk about informal experiences they might have had talking with relatives while taking nature walks, visiting museums, or watching TV programs. Before they leave the first class, it is made clear that the methods instructors are not enamored with the way most science has been taught in our schools. This is made clear so that the preservice students get the message that they should feel open in their writing. The follow-up discussion in the next class shows respect for their fears and attitudes and *validates* their experiences, i.e., accepts them as justifiable responses to these experiences, as any good activity related to a *mirror* should do. They can then respect their own identity, yet begin to approach the teaching of science in a more positive manner. It also informs the methods instructors so that later communication with students can be specific rather than generalized, especially for the few who already have a positive history with science.

During the rest of the term this piece acts as the catalyst for numerous discussions about our students' past histories as science learners and how this history, in most cases, contrasts sharply with the constructivist activities they are facilitating in their field placements. It is a bit like therapy. First they need to

uncover the past and view the pain that causes their aversion. This allows them to be cautiously open to, yet critical of, the experiences they are given with inquiry-based, constructivist science activities. They can then begin anew with gusto another kind of "sciencing" with their own students.

This autobiography, done in concert with some sciencing activities (described in more detail later), allows the student some entree into inquiry science teaching. However, the "outside" world of science is still foreign and alienating to many of these preservice students. The next two activities reintroduces them to science through society's media and through personal contact with some of the "players" in the industry of science.

The Science Times

Each Tuesday you are required to chose one article from the science section of The New York Times and come to class prepared to discuss the article from the perspective of why you chose it, what is important about this research, and why you might want to learn more about it. This should be written briefly in your journal.

A similar assignment can be done with any science magazine or newspaper written for the general public. The students usually don't spend much time speaking about these in class, but by the end of the term, after having answered why they chose the articles and what more they want to know, they begin to admit that there is a large portion of science that is inherently interesting and important to them. After having found relationships between the topics in the weekly articles in the newspaper and the activities that they have done or read in the NSF supported curricula, they seem to become less threatened by the science experiments described in the articles. Having done their own investigations that uncovered some very preliminary concepts related to topics about which they are reading, or seeing experimental design formats in the articles that are similar to ones they have created and refined, the students seem to "bond" (a little) with the researchers and become more willing to fight through the science voca' ulary for meaning.

The students do not all become avid readers of science journalism, although some do. Most, however, are no longer threatened by it and are able to begin using it as a source of STS motivation for their classrooms. Many of them use these current events in science, especially technology or science innovations that relate to the students' daily lives, as extensions of the constructivist science activities that they are doing with the children in their field placements. That is an attitude shift that is useful for a lifetime.

Interview with a scientist

You are required to conduct an interview with a working scientist. This interview process is designed to give you the opportunity to explore how scientists work and to elicit the reasons for their entry into science. We will collaborate on

the parameters for this interview as part of the class discussions. The interview, and your reflection upon it, will be submitted in the form of a paper.

This assignment generally elicits the most moans and groans of all that are assigned, yet by the end of the term is recognized as one of the most important. The assignment is given for two reasons. The first reason is so that each student can make contact with a scientist who might someday invite the student to bring his or her future elementary class to this scientist's lab. The second reason is for students to see that scientists are not all bald-headed, white men who blow up things in a lab.

Each term only one or two people in the methods classes have ever met, or realize that they have met, a scientist. About a month and a half before the interview paper is due, after the class has spent some time uncovering what good science teaching might look like, they brainstorm as a class a set of questions which each individual will ask a scientist. Students are responsible for finding a research scientist. Time is spent differentiating between a research scientist and a technologist (realizing that this sometimes overlaps for some individuals). The students generally find them at universities, hospitals, government agencies, industrial sites, or at relatives' houses.

The types of questions the students ask usually relate to why the scientist chose her/his career. Was there a teacher who influenced them? What type of school experiences in science did they have? What would they recommend for children in science in school? Was there any difficulties with being from a minority population or being a woman in the world of science? Why aren't there more women and minority people in the world of science? Does being a scientist interfere with personal or family life? Is it a lucrative career? Would you become a scientist if you were to begin your life again? What is involved with your research? The methods instructors then suggest one or two questions: How much of science is intuition (i.e., seeing a solution to a problem and not knowing why it is the solution). How much of science is daily step-by-step procedure, either to investigate these intuitions or to continue only a little further beyond the existing research?

The day they hand in their interviews we go over each of the categories and see if there are trends. It is generally interesting to see variances according to the gender and ethnicity or race of the scientists. As a whole, students are amazed that these "gods of science" are pretty ordinary folk who look and speak normally (except when they speak of their research) and were more than happy to do this interview with them. Almost all of these future teachers and their future students are invited to the scientist's lab.

This next assignment is where the students have a place for their voice in science education, and the instructors get a chance to hear it, revel in it, challenge it, and generally just joyfully listen.

Dialogic journal

It is important to look backward even as we move forward into new ways of seeing and doing science. It is therefore important, to help you gain the most out of the reading and the class experiences, to reflect upon these in light of your own experiences by keeping a journal.

Do not use the journal as a way to summarize what you have read or experienced. You should comment on the things you agree and disagree with because of your own experiences as a student, parent, or educator. You should explain how the ideas in this reading or experience will change the way you teach, because you agree or disagree with them. It is a place for you to be reflective—to begin to create your own personal model for educating children by reflecting on various models to which you are exposed.

These entries should contain your personal voice. What are your reactions to sciencing in this course, to your field experiences in your mentors classroom, and to the readings about science and science teaching? Keep in mind also that, given the size of the class, this is the main way I can communicate with you about teaching. It is a major part of your grade and should be taken seriously. Yet it is a place for honesty and feelings—for that is what teaching is also about .

This journal has become the backbone of the course! The students are supplied with numerous readings from magazines and journals which cover a broad variety of issues. There are articles about gender, ethnicity, and race; the state of affairs of U.S. science education relative to the rest of the world; constructivist science teaching; early childhood science activities; cooperative learning; learning styles; inquiry science as a way of teaching reading. For example, two of the best are Watson and Konicek's (1990) article on conceptual change, and Maryann Ziemer's (1987) article on science and the early childhood curriculum, or in another vein, Linda Harrison's (1975) article on research done showing the detrimental effects, especially on girls, of using generic pronouns in science classes. Each term I add and subtract articles. They also read *The Science Times* as described above. They read from a methods text. In order to have a chance to apply some of this theory of how children learn and how to engage children in constructivist science activities, they have a field placement in a public school classroom where they teach science for two hours, two mornings a week. They have been in classrooms themselves for 15 years. Many of them have children who are presently in classrooms and they interact with these children daily.

The preservice students are asked to reflect on each of these as they encounter them. If they are reading an article, then they should relate the ideas in this article to their field work, their own history as learners, and other readings. The focus could just as easily be a field experience. This is the time for interplay between *mirrors* and *windows*. They see their reflections in the *mirrors* of their past science experiences, as well as their reflections as they themselves encounter constructivist inquiry science for the first time. These personal experiences are contrasted with looking through the *windows* of the readings (the words of others)

and the experiences of the girls, non-white boys, and white boys in their field placements. They need to *analyze* each of these and then to *synthesize* them together to make meaning that can inform their teaching. I ask them to describe what their future classroom will be like because of this critique and analysis.

This process is new to them. Many of the education faculty espouse constructivism, but rarely allow our students to construct their own knowledge and understandings based on a synthesis of theory and experience. It is a long term process that occurs during the term; it is a dialogue between the student and teacher. The journals are collected and read and comments are made not about right and wrong answers, but about the level at which the students are engaging in this process. They can redo sections, following suggestions. They can engage in more debate about questions that are asked to stretch their thinking. They can wallow in the praise heaped upon them for real insight into the mechanisms of the learning experience.

This process seems to promote an *attitude* change for most of the students. They begin to see themselves as *having a voice* in the process; in most cases having a *woman's voice* in the process of teaching science. If they have a voice in constructing their world, their profession, then they better understand the voice in science that they should give their students.

Through this dialogue about their readings and experiences, these preservice teachers begin on their journey to a feeling of competence in engaging children in sciencing. However, these beginning positive interactions with science do not change their feelings of incompetence with technological devices. Just as these women needed an appropriate experience with science before they could move beyond their negative attitudes towards science, they also must be provided with a positive interaction with technology if we expect them to include technology in their future classrooms. The following activity is an invitation to the world of tools and machines.

Take-it-apart - technology

In order for young children, especially girls and minority children to have a better chance of acquiring the skills necessary for science and technology careers they should have school experiences where they invent and take apart technological devices. Since many early childhood teachers have not had these experiences themselves, this day will be spent investigating and attempting to repair broken devices that are brought in from home. In addition, a mini invention fair will be held. In order to participate you must bring in from your home some device that is broken. The device can be an appliance or a wind-up toy. Try not to bring things that are dependent solely on printed circuit boards such as TV's, radios, or computers.

For some of the women in the class, this day is the pivotal point, or the catalyst to get over the hill. It is a matter of self esteem; a day of empowerment. It is a step towards overcoming their alienation from technology, and in turn an entree for some into science and engineering.

For most of the the students, including some of the men in the class, a modern technological device is a "black box," that is, some mysterious mechanism which is inside a plastic box which does something for you. Whether it be a hair dryer, watch, toaster, wind-up toy, or steam iron, the device is seen as something only those fix-it type "guys" could take apart and fix.

A cabinet full of tools is kept in the *Children's Science Materials Workshop* (a large room where we teach science methods, both preservice and inservice). These tools are used to build science equipment (e.g., weather instruments and balances) with inservice teachers. The screwdrivers, pliers, wrenches, soldering irons, and glue guns are used for the take-it-apart day. After the first year I did this activity, I realized that in addition to fear of the "unknown," my students had no strategies for taking these devices apart. As a boy I had acquired these strategies from my father on that informal "watch what I am doing" system that males grow up with. By the time I was 11 or so it was apparent to me that you needed to find a linear connection between the *power source* for the device and the eventual *output* of the device. For example, the turn-key on a wind-up toy is connected eventually to the legs that move. If you follow this linearly through, you will discover springs attached to gears. Soon you figure out how the mechanism works based on your past experience with springs and gears (knowledge usually happily, but hastily conveyed from one generation of men to the next). The same holds true for steam irons where the linear connections are from cord to switch, to coil and so on.

Therefore, the class begins by asking, "How does one go about starting to take something apart so that you can figure out how it works and have a shot at fixing it?" The discussion usually begins with pragmatic issues like, "take out the screws," or "keep the pieces in the order as you take them out so you can put them back the same way." Only when I lead them into a discussion by asking "What is the first thing I need to look for when I want to see how something works?", do I sometimes have them consider power sources and outputs and the things connecting the two. A few examples help them to see this process. Without any further ado they get into taking the objects apart!

The students, with a little assistance from the instructors, have figured out how virtually every device they have brought in works. Usually it is only a general understanding, but most of the time it is in enough detail so that we can repair it or decide it is beyond repair. I am amazed at the number of items that can be repaired. The number one broken item brought into class is a hair dryer. We have fixed virtually every one. The problem is usually some hair in the bimetal strip or in the coil. We have fixed hand-vacs (a wire that needed to be soldered), and my all-time favorite, a personal cassette player which had a drive belt that had slipped from a pulley and needed minor adjustment.

I wish you could read the journal entries or hear the comments of most of my students after this class. It is like a revival meeting. Most of them felt so empowered, including those who did not fix their device. They had felt so dependent upon certain men for this aspect of their life. They wanted to give this ability to every girl in their classes. They also understood how knowing the

"science" behind the components in these devices was necessary in order to be able to be a trouble shooter. I highly recommend this activity for an attitude shift.

After this class, students are constantly telling me about "handyperson" repairs they have tackled around the house. Likewise, one or two women in the class describe how they had an older brother who enlisted them in repairing their cars when they were young girls and had always been able to do this type of mechanical activity. Usually they never let their women friends know about this competence for fear of being ostracized. This class was their chance to take the limelight.

If there is time in the term, we follow this with an *invention fair* where the students have a chance to invent things. Students use items from my closet full of "junk" and items from home to make their inventions. There are a number of good books on this topic (Caney, 1985; McCormack, 1991; Stanish, 1981).

Part II - Looking Outward

Most of the above activities engaged students in an evaluation and validation of their own experiences with science—*mirrors*. Each activity also makes them aware of these same experiences from the viewpoints of others, whether they were from the perspective of the predominantly white males who created the milieu in which school science has been traditionally approached, or the Afro-American, Latino, or Asian students in their field placements. This understanding provides the students with *windows* through which to see how they need to approach science in order to be successful in their future classrooms. Once the preservice students have passed this first hurdle of self reflection they then need to be given the tools, materials, and understanding of their uses so that they can be ready to prepare experiences for their future students.

In an effort to give these students an alternative to *chalk and talk* science lessons driven by encyclopedia-type science textbooks, we provide a rather complete collection of NSF supported elementary science curricula—from SAPA of the 1960's to FOSS and its equivalents of the 1990's. The preservice students are engaged in activities from these and in turn engage the students in their field placements in modifications of these. These curricula have been extensively field tested, created by women and men who had girls and minority children in mind, and are teacher friendly, even for neophytes. A careful assessment of the psychological foundations for each of these curricula and syllabi is undertaken so that these students have another *window* through which to see the children with whom they are using these curricula each week.

Before they graduate and seemingly disappear within the great monolith of faceless teachers in our school system in New York City, our students need to view themselves as professionals. They need to become part of a working team in our classes and to make connections with teachers who already see themselves as professionals working together to facilitate exemplary elementary school science. This involvement can provide *group mirrors* and *windows* with which to reflect upon and modify their own profession.

Assignments and Activities

Critique of NSF curricula

There are copies of National Science Foundation supported curricula in the Children's Science Materials Workshop to which you will have access. These represent some of the best validated, appropriate science experiences for young children. During the term we will create a set of criteria with which to judge elementary and early childhood science curricula. As part of a collaborative group you will take home sample curriculum guides from at least 8 of the 12 curricula represented there and evaluate each of them. Try to select some pieces that have topics in common so that approach can be more easily compared. This part of the assignment can be done by individuals, with the group acting as a quality control. When this is completed, the four members of the group should get together and compare the various curricula based also on some additional criteria you will have created while you were evaluating the materials individually. The evaluations need to be written, typed, and submitted.

This assignment is done about one third of the way through the term. By this time the students have internalized most of the criteria for identifying effective science curricula. This insight into criteria comes both from their extensive reading and journal writing and from participating in or observing children participating in appropriate science activities. They are sent off into groups of four to make a list of criteria, and then use these as a springboard to create a more inclusive list in the context of the larger group. The list includes such ideas as: developmentally appropriate; inherently engaging to young children; constructivist in approach; truly hands-on, minds-on; leads to long term investigations; not gender specific; interdisciplinary connections; multiple learning styles embedded in the activities; not too costly; STS approaches included.

The students usually do a fabulous job with this project and uncover strengths and weaknesses that I thought only long term critics would see. For example, they see *FOSS* as very friendly to teachers who have never done hands-on inquiry science, but weak compared to *ESS* as far as constructivism. Although the Nuffield *Science 5/13* from England appears dry and technical to women, students uncover its inherent interdisciplinary nature. Having these groups of students use not only understandings they gained from the assigned readings, but having them also employ their own experiences and observations as the central basis for this evaluation, allows them to experience learning within a modified constructivist format.

Students reveal in their journals that it gives them a great deal of security to be familiar with such an array of effective science resources and to have the skills to evaluate these or additional curricular resources. The *attitude* change here is from one of student to professional. The feeling is one of mastery. The students realize that they have a skill that many of their mentor teachers have not yet acquired. The preservice students have not only realized that their school science was inappropriate, but now they can also discern what is appropriate.

ESSA or SCONYC meeting

ESSA is the New York City teachers association for elementary and early childhood science and holds its annual Science Saturday in the fall. SCONYC is the umbrella organization for all the science education organizations in the city and holds an all-day annual conference in the spring. You are required to attend one of these all day conferences and write in your journals about the experience. Both of these organizations are run solely by local teachers. This will give you an opportunity to meet and socialize with an exciting and excited group of professionals, and add to your library of resources from the handouts at the workshop sessions and the freebies from the exhibitors. Make your professional connections now!

At first there is a lot of moaning and groaning when students realize that they are giving up a weekend day for a class assignment. But by the time this assignment comes along in the term, many of them have already had an attitude shift. Once they have attended one of these days, most students are hooked and begin to identify with the teachers who are attending and presenting at these conferences. They see that these teachers are not much different from them, and these teachers are excited by sciencing in their classrooms. Most of the students join ESSA while they are in the methods class even though it is not required and many maintain their membership when they begin to teach. They are quickly becoming professionals and they begin to have new role models, especially for teaching science in the elementary classroom.

Science and Children *article review*

Choose an article from any volume of the magazine Science and Children *(from 1987 to the present) and talk about why the article interests you and how it informs your approach to classroom science.*

Similar to the assignment to attend a local conference, having students peruse many volumes of *Science and Children* engages them in a life-long relationship with NSTA. Students are amazed that such a resource exists for their use and about 5 students from each class join NSTA as student members just to receive the magazine. About three or four even go to the regional or national NSTA convention. There is nothing more powerful to help move a preservice teacher's attitude forward about teaching science in the elementary school than the comraderie of the elementary teachers at an NSTA convention.

Part III - Putting It Together - Theory Into Practice

There are two additional attitudes that need to be addressed by the students in their quest to be comfortable and proficient at creating appropriate science learning environments for their students. The first is a pragmatic one and is an attitude that has not been overcome by most of the teachers in our schools. Since constructivist inquiry science activities take so much time, most believe there is

not enough time in the school day to accomplish them properly. Second, is the idea that science is an alien discipline, separated from their daily lives and from the other disciplines—literature, art, music, history—that they do consider their own. This distance is further exacerbated when mathematics is added to the science.

Having the students engaged in being scientists, though neophytes at best, allows them to uncover both the process of science that should be the focus of their engagement with their students, and the connections to their own vested subject areas and avocations.

Simultaneous with this personal discovery is an assignment to create their own vision of science at the core of a classroom day. Students begin to develop unit plans in science that are *SEAMLESS.* By the time this assignment is given, the students realize just how motivational and engaging good constructivist inquiry science activities are. They understand how necessary it is for students to design investigations to test their own preconceptions of how nature works. They realize how this leads to additional questions from students which sometimes need to be answered by discussion or by reading about scientific frameworks that have been created by professional scientists throughout history. Unlike most science teachers who spend most of their time answering the questions that students don't have, these students begin to create unit plans that inspire questions of deep understanding.

Of equal importance is their discovery that many of the activities that they have previously seen as science activities, have become writing, math, art, music, and reading activities as well. There does not need to be any separation between subjects during the day. The assignments they should give their future elementary or early childhood students to do at home are also *activities*, many times things to be done with their parents and neighbors. Not only does science become SEAMLESS in the school day, but within the child's whole day. These understandings about teaching various disciplines through one activity only begin when science becomes SEAMLESS within the preservice students' own lives as well.

Science
Engineering
Art
Mathematics
Language Arts
Exercise
Social Studies
Synthesis

If the students are to teach science as part of their school day for years after they leave the university, then they do not need a science attitude, but rather a *SEAMLESS attitude*, an attitude where science takes its natural place within their lives.

Perhaps it is more important in methods courses that more time be spent on attitude change rather than on the acquisition of particular pedagogical knowledge and skills. Perhaps it is more important that teachers want to implement a SEAMLESS curricula or an NSF science curricula than it is for them to have all the skills necessary to do so. There is a limited amount of time in methods courses. What is the appropriate mixture of activities that focus on attitudes, skills, or knowledge? Given what we know of constructivist learning, will preservice students really change their conceptual understandings of how children need to be taught science unless they themselves have undergone a shift in their own attitude about school science? In turn would there be a chance that they would implement the constructivist, inquiry strategies for science learning in their future classrooms? This matrix of assignments has helped students he methods classes shift, and even discard, many of the attitudes they held upon entering the class, and has allowed them the opportunity to select science activities as the core of their classrooms.

Assignments and Activities

Constructivist inquiry science activities in the methods class

Mystery Powders (ESS, 1986), *Clay Boats* (ESS, 1985) and a number of other well known activities are utilized throughout the semester as the material for engaging preservice students in discovering that science activities are simply "figuring out how to figure out" how the natural world works. A land snail activity is used as a model for the *attitude changes* that can occur from the students' engagement in constructivist science.

There is a preliminary activity where each collaborative group is given one or two land snails to observe. The instructions are simple. Do something harmless to the snail or give it something harmless to interact with, and observe how it reacts. This is done for two reasons. To demonstrate to students that the first three parts of the scientific process as described by scientists are to *mess around, mess around,* and *mess around.* The second reason is to point out to the students that if they do not first let kids investigate a new animal or piece of apparatus on their own first, the children will never attend to what you want them to do that is more structured. This is soon born out when the methods instructor attempts to speak with them about their results while the snails are left in front of them. Almost no one attends to the discussion. As soon as the snails are removed there is a new focus in the class. The preservice students realize how powerful a motivational tool these snails will be in their future classes.

In addition to collecting the students' observations about the snails on an experience chart, the methods instructor also begins to point out that some of the "observations" were really conclusions which required testing. This motivates students to begin to speak of how they would design an investigation to validate the preconception. This leads to a parallel chart of all the things they want to know about the snails: Can snails see?; Why do snails release slime?, How can you tell

a male from a female snail?; What do snails like to eat?. Consequently, the design, modification, and doing of the investigations stemming from these would surely engage students and yet allow any teacher to cover many of the concepts and process skills required at a given grade level.

The realization that there were *no right answers* in this *sciencing other than those dictated by nature itself* is another pivotal point in *attitude change*. No longer is the text book or a teacher the definer of truth, but the reliability and accuracy of their own methodology becomes the instrument of assessment. These preservice teachers begin to take personal ownership of science as a consequence of sciencing. This acceptance begins slowly, and expands throughout the term with each further engagement in short or long term investigations. Students are no longer looking at science through someone else's *window*. By accepting science as their own, they are acquiring another *window* through which to see the world.

At this point they are presented with a problem. Do snails prefer to go up or down an incline plane (ramp)? They are shown some materials (cardboard, flat wood pieces, Styrofoam trays, a spray bottle filled with water), and are sent off into their collaborative groups to design an experiment to find an answer to the question. The brevity or quality of these procedures is not questioned. Students are allowed to conduct their experiments for about twenty minutes or so. They are then asked to attempt to draw some preliminary conclusions or *leanings*.

Various groups are asked for their findings and it soon becomes very apparent that there are differences in the results of their experiments. In order to point out that they have been using various procedures, one group is asked to read their procedure word for word. The instructor has handy large size sheets of cardboard and wood so that when they say, "take a ramp," or even if they are careful enough to say, "a cardboard ramp," the instructor pulls out this 4 foot by 8 foot piece of cardboard and sets up the ramp. Likewise if a group says, "a small piece of wood," the instructor "replicates" their procedure with a one inch by half inch piece of plywood. The idea of defining variables emerges full force. In order to reinforce the idea of variables, we speak about the groups who placed the snails at the top or bottom of the ramp to see which way they would go, or the group who placed food at the top of the ramp as part of their procedure.

The next step is most important. One of the variables they discern as important is the angle of the incline. Students are asked to come up with a way of recording the angle so that they can repeat the experiment, but are not given protractors. Unlike most third graders, they don't think of holding a piece of paper next to the incline and simply tracing the triangle. Rather, they begin on the quest of recording the angle by measuring the height of the incline from the table. When discussion demonstrates that the length of the incline matters, they uncover the idea that in a right triangle if you know the side opposite and either of the other two sides you have defined the angle and the triangle. When it is pointed out to them that they have discovered some of the major ideas in the geometry and trigonometry of triangles, they are astounded. They are quite candid about the fact that they never understood nor had an interest in any of this in 11th grade math.

In this process of trying to define the angle, they also realize that they can't even "define" the word angle, despite their years of using it and studying it. This leads to the idea that meaning in mathematics, reading and writing only comes from uncovering the meaning in real life activities and then applying the word to the self made definition. Piaget does not say engaging children at the concrete operational stage in hands-on activities is a nice way to learn about new concepts and skills, but rather he, Gagne, and Bruner, say it is the *primary* way for children to make meaning. Trying to teach reading and writing separate from *doing* is impossible. This is a revelation for the students, who begin to realize that the thinking and problem solving process of science is not that much different from that in reading comprehension and paragraph writing. However, science has the *stuff*. We have the *stuff, the concrete materials, which children can touch and manipulate.* These children can then write about these experiences and make connections between these real experiences and their symbolic representations in writings and numbers. Subsequently, the children can read about topics related to their investigations or read text with grammatical constructions similar to the constructions they created to describe their manipulation of materials (e.g., *if* I do this *then* ...). Once the preservice students begin to understand this insight into the reading-writing process, *a major attitude shift towards sciencing occurs.* They suddenly start to see how they can teach math and reading during this activity and how this is not a science activity at all, but a multidisciplinary activity that one could easily do for two hours a day in their future elementary classroom.

The students in our methods classes live in the city and most live in apartment houses. However, a few live in houses and describe to the class how, even in the middle of Brooklyn, they have snails in their backyard gardens. This leads students to question where we acquired the snails. When we tell them Morocco, they realize that geography, climate and maps can easily become part of a unit that used snails. It wonderfully gets out of hand. Some of the preservice students go on about how snail adventure stories need to be written by the children and about books like *Sophie's Snail* (King-Smith, 1991) and the *Snail's Spell* (Ryder, 1982). The ideas abound. *Positive attitudes* about using science activities as the core of the elementary classroom are further strengthened. This leads them nicely into the next assignment, the Unit Plan.

Unit plan

As you become acquainted with curricula creation during the term you will write a plan for a SEAMLESS science unit that you and your cooperating teacher will use during the term. You will acquire materials, write a plan for both science and related area (math, language arts, social studies, etc) activities. This is the main project for the term and will evolve as the term goes on. As with all other activities, collaboration between members of the class is encouraged, but a maximum of four students may work on a plan together. The collaborators must be from similar grade levels and have some topics and a theme in common.

The creation and implementation of this unit at your site will be a major part of your grade. As the term goes on, we will use a number of investigations from some better curricula such as ESS, SCIS and SCIS3, SAPA, GEMS, AIMS, FOSS, Insights, Science for Life and Living, Science and Technology for Children, or Science 5/13 ("Elementary Science Curriculum," 1988, pp.138-146). *A module from one of these should be the backbone of your unit plan.*

This unit plan with its 16 activities will be part of the one that is required in the math course, so although it should emphasize science and math it should integrate other subject areas and affective activities in a manner that would create a SEAMLESS environment. This is the second largest item to be accomplished during the term and will account for the second greatest part of your grade. It is advisable, therefore, to collaborate with me and your classmates as the term goes on.

This assignment becomes an obsession. It overtakes the students lives. It becomes an all consuming monster. When they are done, it is usually bound, has illustrations and is well over 100 pages. Most of them take it with them when interviewing for their first job. Principals have hired many of them on the spot solely from this plan alone. It is usually based on some NSF curricula, but it has so much more. It has many disciplines woven into each activity. It has hands-on activities for homework and sometimes even social action activities as part of its structure. It has all the daily planning items in it including their reasonings behind grouping students a certain way. It also contains their revisions of 8 activities which were used with children during field placements. Many times these evaluations contain references to articles they have read for the class. Each of these activities takes days to accomplish. They realize the long-term nature of constructivist science. Many times they have revised the NSF activity to be more constructivist, starting with the children's' preconceptions and allowing them to design their own investigations. This is an intellectual piece of work. This is a pragmatic piece of work. It follows the SEAMLESS philosophy that is espoused in the class activity section above.

In order to facilitate this process of seamlessness, groups of students have been engaged in another small project: *Science Song, Dance, Game, or Improvisation*. Science themes can be reinforced through the arts or games. The methods instructor models writing songs about science themes using familiar melodies from popular songs. The instructor also demonstrates some STS improvisations and takes part in role playing. The preservice students then work in groups outside of class to create any of the above, using their own themes, topics, and ideas. Each week some group leads the methods class in a science song, dance, improv or game. It is fun and refreshing and lends a wonderful tone to the class. Many times these are integrated into unit plans. For the students who are especially comfortable with these learning styles, *attitudes* keep moving.

As one of their field-site activities students can have a group of students create a fictional story based on something they have studied in science. The preservice students transcribe it, have the children illustrate it and then bind this into a book. Extra credit is given if they transcribe their book onto a computer with a laser printer (a Macintosh is suggested) and paste up their black-outline

drawings. It is then possible to xerox many copies of the book, which can be read, colored and duplicated.

Field work

Each week students are required to spend at least 2 hours of each of two days in a field placement in the public schools. Most of the teachers they are placed with have been in a summer mentor training program and are involving the children in their classes with constructivist, hands-on science on a regular, if not daily, basis. While in the field, preservice students are expected to teach at least one 40 minute hands-on science activity each week. Most of the students teach two per week. These activities are part of their thematic unit that they have created in consultation with the professor, other students in the class, and with their cooperating mentor teacher. In addition to teaching, students perform other school-based assignments (e.g., a survey of wait-time of teachers in the school and the number of girls in early childhood classrooms engaged in spatial relationship activities).

This field placement is the best attitude changer of all, but does not work without the implementation of all of the above. Once the students are open to working with the children with constructivist, inquiry science, then the enthusiasm and thoughtfulness of the children do any additional convincing necessary. By the time most students have completed their placements, they are convinced of the necessity to do science on a regular basis in their classrooms.

Some Closing Thoughts

The *windows and mirrors* theme provides a metaphor for one of the grounding assumptions of constructivism: that cognitive complexity is related to the subject's recognition of the world's complexity.

Since the preservice students in our methods classes have constructed their own understanding of what science is and their relationship or lack of relationship to it before entering our class, we must give them a chance to reconstruct this preconception if we expect them to hold a more accurate one by the time the class is over. Lecturing or telling, as usual, will not work. It is an interactive process by which they simultaneously uncover what science is and how to create an appropriate learning environment for engaging children in science. It is therapy in that these mostly female students investigate and validate their less than desirable relationship with what they thought was science. By engaging in being a scientist and studying how to teach science, students can come to a new relationship with science and technology. They cannot embrace science through someone else's window of seeing, but need to create their own place *in* science, real science, so that they can assist their students to do the same. Each of the activities and assignments has helped facilitate this process. Although at first perusal the activities and assignments seem unrelated, they support one another

and intersect to form a matrix with the *mirrors* and *windows* becoming intertwined until they become almost indistinguishable.

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An Analogical Technique for Teaching Question-Asking Skills to Science Teachers

Roger A. Norris

Questioning skills are a critical part of instructional expertise, and thus are essential for both preservice and inservice teachers to master. I present questioning skills to the teachers and students I work with as a series of three one-hour lessons which address the following subskills: (a) choosing the right questions, (b) asking questions effectively, and (c) responding appropriately to student answers. To help teach the second of these subskills, "asking questions effectively," I have developed a series of vignettes, involving throwing and catching tennis balls. These vignettes are analogous to a variety of question-asking behaviors. This activity has proven to enthusiastically engage students, while at the same time requiring them to employ some sophisticated critical thinking skills as they develop a model for reflecting on their own question-asking technique.

The activity that will be described here requires about an hour and follows an hour-long lesson on "asking the right questions," during which students learn to generate convergent and divergent questions at various levels of Bloom's taxonomy. The activity is followed by a lesson on "responding appropriately to student answers", during which students develop skills in praising, probing, prompting, and redirecting student answers. I typically use the activity with 30-50 science methods students, though I have effectively used this activity with 8 to 120 students in settings ranging from elementary school teachers' lounges to university lecture halls.

Introducing the Lesson on "Asking Questions Effectively"

When presenting an extended workshop on questioning skills, I find it worthwhile to take the time required to guide participants so that they inductively discover the idea that playing catch with a ball is, in many ways, analogous to asking questions and receiving answers. With the time constraints inherent in a science methods class, however, I typically streamline this step by beginning the lesson by holding up a tennis ball and saying, "This looks like a tennis ball, but actually its a question." Then I toss it to someone and ask, "What did I just do?" (Response: 'Asked a question!') Then I'll have her toss it back, and ask, "What did she just do?" (Response: 'Answered the question!')."

Once it is clear the analogy has been established, I conclude the introduction by saying, "The way you ask questions can have an enormous effect on how well

your students learn. By visualizing asking questions and receiving answers as being similar to playing catch with a ball, you can really strengthen your question-asking skills! Now we're going to do a series of activities using this analogy. After each one, we'll stop and describe what happened, and discuss how it might be analogous to classroom questioning."

Presenting the Activities for "Asking Questions Effectively"

The following analogical activities are ones that have over the years proven to be most effective in teaching questioning skills. Though I have tried many others that have not worked, and though there are several important questioning skills for which I have yet to find effective analogical models, the ones presented here do appear to provide vivid, thought-provoking, and informative experiences for students.

As I teach this lesson, I establish a pattern consisting of three phases for each activity: (a) Demonstrate the activity, (b) Students present their perceptions of what happened, and (c) Students describe the ways in which this activity is analogous to some aspect of teacher-questioning. In the following examples, I will describe each of these phases as they typically occur in the classroom, including a description of the activity, samples of typical student perceptions of what happened, and student descriptions of the analogy that was represented.

Activity #1

Stand in the middle of the classroom, call a student's name, then toss the ball to him or her. Repeat this a few times. Then say, "This time I'm not going to say WHO I'm going to toss the ball to; I'm just going to toss it to someone!" (At this point, it's effective to hold the ball back as if you're about to throw it, and turn slowly around the room. Students invariably lean forward in their seats a little, and become very still and alert.) Then, without throwing the ball, stop and ask students to describe what they experienced.

A typical student response is, "When you called someone else's name before you threw the ball, I was able to relax, because I knew I was off the hook, but when you said you would just throw it to anybody, without saying who, I had to be alert the whole time because I knew I might get it."

Students describe the analogy as follows: "If you call someone's name before you ask the question, the other students don't have to listen closely to the question, or try to think of an answer. If you ask the question then make everybody sweat for a while, most of them will probably have an answer ready just in case you call on them."

Activity #2

Ask, "Who would like to catch the ball?" When there are a few hands up, toss the ball to one of the volunteers, then ask him or her to toss it back. Repeat this

a few times, then state, "Well, it's clear to me that this entire class really understands catching and throwing, and we can move on to something else!"

Student reactions: "How could you know we were all good at it? You just threw it to those people who volunteered, and the people who volunteered were all probably pretty good at it. If I were incompetent, I'd never volunteer!" "As long as I never volunteered, I'd never have to pay attention or learn to catch."

Student generated analogy: "If you just call on volunteers, you're likely to get a distorted impression of how well the class understands something. You'll get a better picture if you call on non-volunteers too. If you just call on volunteers, it will be easy for some students to just quit paying attention. There may be some kids who want to answer but don't want to volunteer, and they'll never get a chance to participate."

Activity #3

Toss the ball with some force to a male student across the room, then have him toss it back to you. Next, move close to a female student and toss the ball to her in an elaborately gentle manner. It is rare that this needs to be repeated more than once before the women students in the class begin protesting indignantly, though many of the men will be completely baffled at the women's reactions.

The discussion of this activity is invariably a lively one, quickly addressing several aspects of bias and equity. Typical student comments include, "How come you were throwing it so easy to the women? Do you think we can't catch?"

"There's nothing wrong with that. It's just a fact that girls (sic) can't catch as well!"

"You can't make that assumption; plenty of women athletes are better than most of you guys!"

"Well, maybe some, but you'd embarrass most women if you threw it to them hard and they couldn't catch it! They just don't have the skills or the interest."

"But even if a woman wasn't very good at catching a ball, she'd never get any better if all she ever got was really easy throws!"

Student generated analogy: "You can't make assumptions about who can answer what kinds of questions based on whether a student is male or female, black or white, able-bodied or disabled, etc."

"It's important for each student to feel challenged once in a while—not intimidated or anything—just stretched to their limits, otherwise they'll never improve."

Because there often exists some skepticism that teachers actually ask questions differently based on gender, ethnicity, handicap, seating location, etc., this is an excellent opportunity to describe research findings and recommendations regarding interaction bias, such as in Sadker and Sadker (1982) and Brophy and Good (1974). This is also an opportunity to create some anticipation for future lessons specifically devoted to equity issues in the science classroom.

Activity #4

This activity includes some good-natured fun and provides some relief from the often emotion-laden preceding discussion. I begin by holding up three tennis balls and asking, "Who can juggle?" I have found that there is almost always someone who will be proud to demonstrate their ability to juggle, much to the delight of the other students I interrupt their performance by saying, "No, no, no, that's not what I was look ng for." Then I take the balls from the crestfallen student and juggle them usi g a different technique than the student used, saying, "Now, *that's* what I wan :d!" (If you're not a juggler, it should be equally effective to have another stuuent do the juggling.)

Typical student reactions include, "Hey, that's not fair; she did what you asked!"

"There was nothing really wrong with what she did. You just weren't clear about what you wanted."

Student generated analogy: "You have to be really clear when you ask a question. Sometimes you'll get answers that are right, but you didn't expect them, or they're different from what you intended. You have to ask questions precisely and listen to answers very carefully."

"Students shouldn't play the game of 'guess what answer I'm looking for'. They shouldn't have to read your mind."

Activity #5

I begin by stating, "Let's say several of you disagree about an issue. Now we'll have a class discussion using questions and answers." Toss the ball back and forth from you to one student, then from you to another student, then from you to a third stuuent, then from you to another and another. It's helpful here to make some comments like "Well, you certainly have a strong opinion, John!" and "Oh, so you think he's dead wrong, huh Lisa?" and "Well, that's an angle that I don't think either John or Lisa has considered!"

Students usually react by making comments such as, "Why did we have to throw the ball back to you every 'ime? It would have been better to just have them toss it back and forth to each othe."

"Discussions would be better sometimes if the teacher didn't mediate and interpret everything. Students should get to interact directly with each other. As long as things don't get out of control, the teacher should probably stay out of it!"

Activity #6

This final activity is a simple one, yet it addresses one of the most common questioning errors. It requires some sophisticated analogical thinking from students, and usually some skillful guidance from the instructor in order for students to recognize the analogy.

I begin this activity by throwing the ball into the air, then catching it, and saying, "I caught it, right?" I then repeat this pattern several times, using phrases

like, "I caught that, wouldn't you say?", "That was a catch, wasn't it?" or "You can all see I caught that, can't you?" I conclude this demonstration with a statement such as, "Well, that's great; I've clearly taught you all how to catch!"

Student reactions: "No one really caught or threw the ball—we just had to agree that you did."

"We just watched and listened, we didn't have to do anything."

"Just because we saw you catch the ball doesn't mean we learned how to catch it."

In this phase, the students may need some skillful guidance in order to develop the concept of directive questions. When students begin to understand this concept, they will make statements such as, "If you say something like 'sodium hydroxide is a base, right?', all students have to do is agree with you, they don't really have to know anything."

"It's important that students have to come up with an answer, and that you don't just give them the answer when you ask the question."

Concluding the Lesson on "Asking Questions Effectively"

Because this lesson tends to be pretty free-wheeling, it is especially important to end the lesson with an effective closure, in which students reflect on, articulate, and summarize the learning they have just experienced. This can be done by simply having students generate lists or narrative summaries of question-asking techniques which tend to be more effective, and those which tend to be less effective. In a workshop setting or when the lesson extends to additional sessions, a very powerful reinforcing technique is to have groups of 3-4 students take turns acting out a question-answer exchange that includes one skill used effectively and another used ineffectively. After each group performs, the other students analyze and critique the questioning technique of the person playing the role of the teacher.

Follow-up Activities for "Asking Questions Effectively"

Because not all questioning skills seem to lend themselves to this analogical teaching approach, this lesson needs to be followed by one devoted to other skills that are considered important, such as asking only one question at a time, and not habitually repeating student answers. I then have each student present a 5-minute microteaching segment which must be a series of questions and answers. These are then analyzed and evaluated using the criteria we have developed for effective question-asking techniques. A fascinating phenomenon which almost always occurs is that, as students become familiar with good questioning techniques and learn to identify poor techniques, they become brutal critics of their professors, and revel in voicing these criticisms during class. I really encourage this practice, though I insist no names be used. Needless to say, this keeps me on my toes regarding my own questioning technique, knowing (from experience) that my students are *entirely* merciless when they catch me using poor technique!

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Teaching Teachers to Use Operational Questions

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One of the challenges in elementary school science is to design instruction which best corresponds to the capabilities, interests, and needs of learners whether they are children or preservice teachers. People of all ages at some time or another are captured by the mysteries of nature and express their need to know through "why" questions: Why is the sky blue? Why are sunsets red? If hot air rises, why is it cold on mountain tops? Although these are wonderful questions and deserve answers, the answers are not likely to be understood unless the learner has or acquires the knowledge upon which the answers or explanations build. For example, understanding why the sky is blue sky and sunsets are red requires a rather sophisticated knowledge of light (wavelengths related to color and scattering by particles). Often, children and their teachers curiously ask the "why" questions but do not have the knowledge nor can they easily acquire the knowledge needed to construct or understand the answers. It is understandable then, why teachers sometimes shy away from science; they know that the children will ask the questions, but they but do not have the answers or know how to communicate the answers to children. Rather than avoid science or dismiss the "why" questions outright, there is a viable strategy for responding not only to "why" questions but to observed phenomena in general. The strategy is to guide the learner into asking and answering questions which can be answered through observation and/or experimentation. Dorotny Alfke (1975) has called these operational questions. What follows is a description of how I use a learning cycle approach to teach methods students about operational questions and their use.

Communicating the Problem

I ask my students to consider the following scenario:

> You are greeting students as they are filing into your afternoon science class. A bright eyed fifth grader tugs at your arm and excitedly describes a curious story about an incident that occurred at morning breakfast. The student observed her mother using a paper towel to clean up a glass of water accidentally spilled on the kitchen floor. The child asks, "Why do paper towels soak up water so easily?"

I challenge my methods students to think of a meaningful reply to the little girl's question. As my students share their proposals, I purposefully avoid making value judgements regarding the quality of their responses. The responses

are varied and reflect my students' own experiences as children asking similar questions. Our disc ssion generally leads to the following options:

1. Demonstrate your competency in science by carefully explaining that because water is polar molecule, adhesive and cohesive forces cause the capillary action for water absorption in the paper towel.
2. Recognize the complexity of the required response and simplify the explanation by saying, "Since the paper towel is soft, it soaks up water easily."
3. Seize the opportunity to involve the student in extra credit research and refer her to the librarian by saying, "That's a great question! Why don't you ask the librarian to help you find the answer and share it with us tomorrow?"
4. Be honest with the student and follow up with a qualifier, such as, "I'm not really sure how to answer that question. Let me check it out tonight and I'll let you know tomorrow."
5. Recognize how irrelevant the question is to your science program and respond, "That's a very good question that has a very complicated answer. Be patient, you will learn about that when you take physical science at the middle school".
6. Smile warmly and change the subject.

Obviously, none of these responses will be very productive for the little girl. She is eager to understand the astonishing behavior of the paper towel. Her curiosity has been aroused. She is interested in learning science. The problem is that she does not have an adequate knowledge of physical science or the prerequisite experiences required to understand the underlying principles that explain the phenomenon. Furthermore, any of the above responses may only reinforce the percepti n held by many children (and elementary teachers) that science is much to complicated for ordinary people to understand.

I tell my students that science teachers have another option which is easy to use and productive for inquisitive children. Teachers might respond, "What a great observation! I'm not exactly sure why paper towels soak up water so easily. But let's see if we can experiment with paper towels and learn something about how they soak up water."

At this point my students are ready to actively participate in a learning cycle sequence that will model the method that I would use to teach children (and teachers) how to investigate with operational questions. We begin with the following hands-on, exploratory activity.

An Exploration Activity

I model the following procedures as I give directions for the activity:

1. Cut a 3 cm X 15 cm strip from a paper towel. Fold the strip in half along its length.
2. Pour tap water into a small baby food jar to a height of approximately 2 cm.

3. Place or stand the folded paper strip in the jar.
4. Observe the paper towel and the water. Make a list of your observations. Be careful not to make inferences. Remember that an observation is a piece of information that we gather with one of our senses. An inference is an interpretation of something that we observe.
5. As you observe the folded paper towel standing in the jar of water, make a separate list of questions that are related to what you are observing.
6. After about 5 minutes remove the paper towel and lay it on a sheet of paper. Continue to make observations and record any questions that come to mind.
7. Work together in groups of three. One group member will get the materials; one will record the group's observations; and one will record the group's questions.

The materials (1 pair of scissors, 1/2 cup of tap water, 1 sheet of paper towel, and 1 small baby food jar) are acquired and the activity begins. When each group has had sufficient time to observe the paper towel and ask related questions, we record observations on one chalkboard and the related questions on an adjoining chalkboard.

I direct attention to the list of observations compiled on the chalkboard. As we analyze the list, we find that it often contains inferences. Here we carefully differentiate the observations and inferences. For example, "the paper towel sunk into the jar when it became wet because the water made it heavier" is an inference. However, "the water rose slowly up the paper towel when it was placed in the jar" is an observation. I make it clear that we have not answered the initial question: "Why do paper towels soak up water?" We have, however, made careful observations which describe the phenomenon. The list of observations is retained for future reference.

Next I direct student attention to the list of questions on the second chalkboard. I read all of the questions aloud but carefully avoid answering the questions. I accept all questions that are reasonable and help the students see how many of the questions can be traced directly to one or more of the observations.

Concept Introduction

Discussion

Now I have my students reanalyze the list of questions by asking them, "What questions on our list could be easily answered by doing something with the paper towel and water?" These questions, which are answered through action and observation, are defined as operational questions.

Pedagogical content

Operational questions directly involve learners in science inquiry. They enable investigators to obtain first-hand evidence regarding a phenomenon of interest. An operational question requires the investigator to observe and often manipulate concrete variables; it implies what the learner must actively observe or do something with the materials to obtain an answer. In short, asking operational questions empowers the learner to become an independent researcher and enables her or him to learn more about those puzzling encounters with natural phenomena. Dorothy Alfke (1974) described operational questions as questions that are asked by, meaningful to, and potentially productive for the learner.

Operational questions are often "what if..." questions. They do not begin with "why." When experienced researchers observe an interesting phenomenon, they often begin their inquiry with a "why" question, but usually set that question aside as they ask and answer operational questions which are designed either to further explore the phenomenon or to investigate hypotheses associated with possible explanations. Ultimately, all proposed explanations (answers to "why" questions) must stand the test of operational questions.

The inquisitive science student, when faced with an interesting "why" question, often seeks answers from someone or probes a book for an answer. Unfortunately, the answers are not always there nor are they understandable when they are found. At this point the student can give up in frustration or be guided by a teacher into asking and answering operational questions associated with the interesting phenomena and question. By engaging in asking and answering these operational questions, children remain connected to the phenomenon which initially captured their interest. As they seek answers to the operational questions they also develop greater knowledge about the properties of objects and how those objects interact with one another. In addition, they have the opportunity to develop science process or investigatory skills such as manipulating and controlling variables, operationally defining, measuring, distinguishing observations and inferences, constructing and interpreting graphs, and so forth.

Pre-service elementary teachers (and elementary science students) can easily learn how to generate operational questions. Allison and Shrigley (1986) found that if elementary teachers modeled the use of operational questions in science class, their students asked significantly more operational questions than students in a control group where operational questions were not modeled.

Concept Application Activity

After introducing the concept of "operational questions" and presenting reasons for using operational questions with children, I challenge my methods students to refer back to the list of observations and related questions and create operational questions related to any observations or non-operational questions which were asked. Examples of operational questions generated during the exploration and application phases of the paper towel investigation are:

- How does the kind of liquid (muddy water, clear water, alcohol, soapy water) determine how much liquid will be soaked up?
- Does the temperature of water make a difference?
- Will a tightly rolled piece of paper soak up water faster than a loosely rolled piece of paper?
- What are the properties of fast "soaker-uppers" and slow "soaker-uppers?" How will shiny paper, notebook paper, and towel paper compare as "soaker-uppers"?

After generating more operational questions, my students carry out additional investigations. We then compile a list of all the their discoveries and make a few inferences regarding the "soaking" process. As a consequence of these operational questions and the associated discoveries, my students have learned that good "soaker-uppers" have a rather loose "weave" and that poor "soakers" either have no "weave" at all or a very tight "weave," and they have learned that different liquids climb (or are soaked up) at different rates. Someday this acquired knowledge might help them more meaningfully understand a scientific explanation which incorporates ideas such as capillary action (related to "weave"), adhesion, and cohesion (related to properties of liquids).

Although the original question "why do paper towels soak up water?" is not answered, interest in "soaking" and enthusiasm for investigation is generated and sustained. My students recognize this and hopefully see operational questions as ways to respond to children's "why" questions while sustaining their interest, developing their inquiry skills, and establishing the physical knowledge the children need for a more meaningful understanding of abstract concepts and explanations.

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Authentic Dialogue: Methods for the Elementary and Middle School Science Methods Class

Michael Kamen

The question posed by the first-grade teacher to her students is whether or not snails can smell. Several children point out that a snail does not have a nose and therefore cannot smell. Another group of children disagree with this conclusion and refer to their experimental data, which describe a snail turning away from a Q-tip soaked with liquid smoke before actually touching the Q-tip. The teacher asks what she can add to the class journal that will satisfy everyone. The debate continues until one child says that he thinks he has an answer. All the children focus on this quiet boy. He says that the snails must "feel" the smell with their faces. A sense of relief and satisfaction fills the room as all the children nod in agreement and accept the statement, "A snail feels smells with its face," as the teacher adds it to the journal under *Can A Snail Smell?*

This discussion is an example of authentic dialogue. Children are asked to discuss their questions and, through debate and consensus building, develop models that explain all the data presented by members of the class. The focus of an authentic dialogue is understanding and consensus building rather than satisfying the teacher with specific answers. This is not an easy role for a teacher and requires clear goals, a good knowledge of the content being discussed, and the ability to withdraw from the center of the discussion while still maintaining the leadership position in the class.

Authentic dialogue occurs when children are sincerely engaged in a meaningful conversation related to the concepts being taught. The purpose of the conversation is to develop an explanation, come to consensus, or help to complete a meaningful task. These discussions differ from traditional discussions in that—from the child's perspective—the teacher is not standing in judgement of the comments made. The judges are the other children, the final results of the projects or experiments, and the child's own satisfaction with his or her understanding. In preparing teachers to plan lessons and lead discussions that facilitate authentic dialogue, a number of instructional strategies are used.

Modeling Authentic Dialogue in the Methods Class

There are two levels at which modeling can occur. At the first level the instructor presents lessons to the students as would be presented to children. The instructor then leads the class through activities and discussions that incorporate authentic dialogue. It is important to carefully choose the lessons so that the adults

have real content issues to debate. At the second level the students are asked to reflect on the lessons and discuss pedagogical issues, including the role of language in the lesson. The instructor leads these discussions in a way that encourages authentic dialogue. In this way the students both experience model lessons and, through their own authentic dialogue, explore key issues in teaching science.

Providing Opportunitles for Students to Observe Model Lessons with Children

This is perhaps the most difficult and important strategy for helping preservice teachers learn how to promote authentic dialogue in their future classrooms. The ideal scenario is to place students in classrooms with teachers who are already skilled in this area. Unfortunately, in many situations there are a limited number of such classrooms, administrative restraints on placing students in selected rooms, or no field experience associated with the methods course. There are several alternatives, however:

1. Videotapes of model lessons can be used during class sessions.
2. Exemplary teachers can be brought in to discuss their methods of promoting authentic dialogue with their students.
3. Students can observe the instructor teaching children from a local elementary or middle school.

Providing Opportunities for Students to Teach Lessons With the Goal of Promoting Authentic Dialogue

It is important to provide guidance and feedback before and after each lesson. The ideal situation is for the students to teach lessons in elementary or middle school classrooms where the children frequently engage in authentic dialogue. Alternatives may include micro-teaching to other methods students, bringing children to the university, setting up an empty room in a local elementary or middle school as a science lab, and sponsoring classes for children at an informal site such as a nature center, zoo, or museum. It is critical to choose a setting which maximizes the instructor's input and control of the experience. At Auburn University we have success with a two-week summer environmental class. Children come in for about two-and-a-half hours in the morning and are taught by undergraduate methods students in science, social studies, and math.

Presenting a Clear Instructional Model

A clear intructional model can help beginning elementary or middle school science teachers organize their plans and adapt their resources to a pedagogical approach in which authentic dialogue is promoted. Three such models are described below.

Investigation-Colloquium Method

The Investigation Colloquium Method (I-CM) provides a valuable framework for incorporating authentic dialogue into science lessons. Brenda Lansdown (1971) developed this method of teaching science, which is based on Vygotsky's (1962, 1978) theories about the relationship between thought and language. Her instructional strategy combines concrete experience with student verbalizations.

The colloquium in this instructional model addresses the need to include verbalization or student talk as part of a learning experience. After an investigation with concrete materials, the children discuss what they have learned. They do not simply answer the teacher's questions but talk, debate, argue, and come to consensus with each other. Lansdown discusses the process.

> This growth (conceptual) may be described as moving from (1) concrete, personal involvement with structured materials and the preverbal thought this involvement engenders, to (2) interaction of thoughts and words as observed data are presented at the beginning of the colloquium, to (3) interaction with words and thoughts of co-workers, to (4) the formulation of explanations and, finally, to (5) testing the explanations. (p. 121)

The Investigation-Colloquium Method is a well-structured and planned approach to teaching science which gives students opportunities to learn spontaneous and scientific concepts. George Tokieda (1982) describes the method:

> The method (I-CM) of approach is based on the fact that children (and adults) learn best by doing and then talking about their discoveries. During the investigation, children experiment with materials which the teacher has carefully structured around predetermined concepts and they discover the concepts which are now in their hands, so to speak. During the colloquium, the teacher encourages the children to say what they have discovered in their own words and tries to take a back seat in the discussion. Through this collaborative peer group dialogue, the children begin to formulate their understanding of the concepts which move from their hands into their heads through the vehicle of language. (p. 36)

The students participating in the Investigation-Colloquium Method are given opportunities to verbalize their discoveries, questions, and observations. The combination of the verbalizations and the concrete experiences follow Vygotsky's notion that learning is the bridging of scientific and spontaneous concepts.

Two research studies have examined aspects of the Investigation-Colloquium Method. Eugene Trainor (1978) compared oral statements of students with different methods of discussion following hands-on science investigations. One

treatment group were engaged in a colloquium that followed Lansdown's guidelines. The second treatment group followed the guidelines presented in the *Elementary Science Study* teachers' manuals (Educational Development Center, 1971). In this second treatment group the teacher was non-directive and passive. In the control group the classroom teacher was present instead of the researcher. The role of the classroom teacher was passive during the discussion.

The results supported the Investigation-Colloquium Method as facilitating conceptual growth. The students' verbal statements were analyzed. The students in the Investigation-Colloquium Method group made about four times as many statements as the other experimental group and the control group. In addition, the statements were at a higher level of thought. This level of thought was based on Vygotsky's (1962) hierarchy of conceptual thought.

Another study (Brooks, 1988) evaluated the implementation of the Investigation-Colloquium Method in an elementary school. Brooks found that the target performance goal of a 30-percent increase on textbook test scores was achieved.

The Investigation-Colloquium Method can be described in a number of discrete steps. The steps are presented in a sequence; however, the model is somewhat fluid with the teacher moving back and forth between instructional modes.

Concepts

The teacher decides on the concepts that will be included in a lesson or unit of study. It is important for the teacher to be knowledgeable about the concepts and their relationship with major themes in science. All other steps should support the development of these concepts and should be evaluated in terms of how well they help students understand these concepts.

Materials and Equipment

The materials and equipment are presented to children to start the investigation. The teacher usually begins with a statement such as, "See what you can discover about..." The initial structure for the investigation comes largely from the selection of materials and how they are presented. The teacher chooses materials that prompt the children to focus on the targeted concepts and that allow them to observe events that will motivate them to want to know more.

Data Charts and Student Documentation

Additional structure and accountability for the children during the investigation comes from the type of documentation required by the teacher. Data charts can help children focus on specific concepts. Science journals, notes, and learning logs (in which children state what they have learned) all contribute to each child's accountability and can help the teacher assess the children's understanding of the concepts.

The Colloquium

The colloquium is a discussion in which the teacher requires the children to respond to each other to create a list of the facts learned and conclusions reached from the investigation. A fact is defined as any statement the whole class agrees on. The teacher keeps a scientist's log of the facts. Misconceptions and questions can be addressed through additional investigations, mini-lectures, creative drama, research materials, and other available instructional resources.

Creative Drama

Creative drama is often used during the colloquium to help students explore a concept they are trying to understand. The teacher sets up the situation and roles for the children but allows them to decide how to act it out. This pantomime should provide the children with an opportunity to develop and communicate a model demonstrating their understanding of the concept, not just reproduce what they have observed. This will give the teacher insight into how the children are thinking about the concept as well as provide a concrete experience and context for children to discuss their understanding of concept.

Mini-Lectures

With sufficient concrete experience and ownership of questions about the topic being investigated the children will reach a point at which they are ready to assimilate factual information they may not be able to discover on their own. This information may be presented to students through anecdotes, written material, videos, computer software, or guest speakers.

Closure/Technology Projects

Children are asked to apply previously-learned concepts to solve a problem or complete a task. The project should give the students ownership of the problem or task; it should be something they see a real purpose for doing beyond being a required assignment. If the concepts learned must really be used in completing the project they are reinforced for the children, and the teacher is better able to assess their understanding.

The 5-E Model and The Learning Cycle

The BSCS 5-E Model and The Learning Cycle (SCIS) can also serve to stimulate authentic dialogue. Although more general and less focussed on authentic dialogue than the I-CM, they are consistent with this pedagogy.

The Learning Cycle consists of the exploration, invention, and discovery stages. The exploration stage includes opportunities for children to discuss their questions and ideas in their own language. During the invention stage children

continue to discuss their data, experiments, and ideas. At this time they are introduced to formal definitions of terms and concepts that should become a part of their discussions. During the discovery stage, children are required to explain new applications of concepts.

The 5-E Model contains five steps: engagement, exploration, explanation, elaboration, and evaluation. The engagement step encourages children to develop their own questions that the following activities may help to resolve. The students' ownership of the learning is an important element for authentic dialogue to occur. The exploration step allows opportunities for children to discuss their ideas in their own words as they work on hands-on activities. In the explanation step children are asked to verbalize their ideas and share discoveries with their peers. A goal in this step is to help the children use scientifically-correct terminology in their discussions. The elaboration step extends children's understanding by having them apply their understanding in a new context. Children are encouraged to discuss and debate their ideas as part of this process.

Helping Students Understand the Theory and Research Supporting Authentic Dialogue

A good methods course should expose students to a solid theoretical base and research findings that support the instructional model and pedagogical approach presented. A theoretical base for authentic dialogue can be laid by drawing heavily from Vygotsky and focussing on the connection between thought and language, the importance of peer interactions, spontaneous and scientific concepts, and Vygotsky's developmental schema of conceptual thought. David Hawkin's (1983) writing about the limitations of traditional teacher talk and Zeuli's (1986) discussion on the zone of proximal development in the everyday classroom further support Vygotsky's theories.

Giving Students Specific Techniques for Teaching Children

A number of specific strategies presented to methods students help them promote authentic dialogue with children. Authentic dialogue about these ideas often emerge during discussions with methods students about model lessons presented in class or observations from lessons with children. Some of the specific strategies which facilitate authentic dialogue are:

1. Keep a class journal of statements that everyone in the class agrees with. The process of coming to consensus creates the need for children to debate and discuss concepts being taught. This can also be used throughout the methods course as a way of recording concepts about teaching science.
2. Children can record data from hands-on investigations on a large classroom data chart. In this way patterns and discrepancies become obvious, which encourages authentic dialogue between the students when they share results and discuss conclusions.

3. Creative drama can help students understand and discuss interactions that may otherwise be too abstract. A number of research studies support creative drama as a facilitator of language and conceptual understanding (McIntyre, 1974; Paley, 1978; Synder-Greco, 1983; Siks, 1983; Stewig & Vail, 1985; Kardish & Wright, 1987; Sarratore & Bell, 1989; Norton, 1989; Kamen, 1991/1992).
4. Children can be asked to complete tasks that have a real purpose and are related to the science concepts. With a sense of ownership by the children, the discussions required by the project are real and meaningful and invite dialogue.
5. Teachers can observe students during hands-on activities and group work. A child can be asked to discuss an idea or experimental observation made earlier. Although obvious to experienced teachers, this may need to be made explicit for preservice teachers and can help them in leading a discussion.
6. Teachers can analyze their class discussions for the number of comments made between students rather than directed at the teacher. A diagram that tracks the conversation allows a teacher to assess the overall pattern. To make a diagram like this you must represent the teacher and every student in the class with a number or their name. Simply move the pencil to each person who talks without lifting it from the paper. A diagram with many lines going to the teacher generally indicates a discussion with fewer opportunities for authentic dialogue than one that has more lines from student to student. These charts can be used during model lessons presented to a methods class, micro-teaching, or lessons with children.
7. Ritualize the formal discussions in which the teacher is encouraging authentic dialogue by expecting children to come to consensus and talk to each other rather than to the teacher. Giving these discussions a name, such as *colloquium*, helps the children understand what is expected of them.
8. Seat the children in a circle away from materials used in hands-on investigations. Discussions attempted in violation of this guideline result in the children being distracted by the materials, less engaged in the discussion, and less likely to become involved in authentic dialogue. This can be clearly demonstrated in a methods class by leading a discussion with the students at tables with hands-on materials in front of them.
9. When children are reluctant to speak, a teacher can get the ball rolling by going around the circle asking each child to state an observation or inviting specific children to share their ideas.
10. The teacher should facilitate the discussion between children rather than engaging in direct dialogue with a child. Statements made by children can be restated and clarified by the teacher making everyone feel listened to. Clarification by the teacher can help the children see ways to resolve conflicts, which may include repeating experiments or designing new ones. For example, a response that would encourage authentic dialogue about why a balloon placed on a bottle has inflated might be: "We have two explanations. Sarah s idea is that as the air is heated it expands, needing more room, and Joe's theory is that hot air rises so as the bottle is heated the air rises into the balloon. How can we test these ideas?"

Lesson Plans that Support Authentic Dialogue

The following assignments call upon methods students to incorporate strategies into their lesson plans that can facilitate authentic dialogue.

Clearly-defined concepts

To be an effective leader in a discussion in which children are talking to each other it is important for the teacher to have a good understanding of the concepts being taught. Methods students can be asked to start each lesson plan with a clear and complete description of the concepts. A hierarchy of broad, sub, and specific concepts helps students to see connections to other areas of science and to children's language. The broad concept is an overlying theme in science, sub concepts are statements describing relationships and definitions using technically-correct terminology, and specific concepts (or children's concepts) are ideas that are expressed by children in everyday language.

Selection of materials

The choice of materials and how these materials are presented to students will prompt specific questions, investigations, and ideas. Students explain how the materials they selected and the way they are presented for hands-on activities will promote questions and discussion about the selected concepts.

Documentation

The method of documentation influences the concepts on which students will focus and can facilitate the recognition of patterns and relationships. Students are required to write two different lesson plans using the same hands-on materials. Their task is to create two different data charts and explain how each chart will focus the children on different concepts.

Creative drama

Creative drama can facilitate authentic dialogue as children attempt to make sense out of an abstract concept. Methods students write a lesson plan in which children are asked to pantomime or act out the concept.

Application assignment

A method of encouraging authentic dialogue is to present a real and meaningful task or problem to children. Methods students write lessons in which children must apply concepts learned to complete the task or solve the problem. Students will struggle when trying to develop an activity that has meaning for the children and requires them to really use the concepts they have learned. However,

with support from the instructor the students will see the importance of the children having ownership of the activity and how that relates to authentic dialogue.

Conclusion

A classroom comes alive when a teacher successfully engages children in authentic dialogue. One goal of a science methods course should be to help preservice teachers experience, recognize, and strive for student interactions of such quality that the children are totally engaged in their discussions and pursue their investigations with interest and ownership.

Promoting authentic dialogue does not come naturally to most beginning elementary and middle school science teachers, however. They have probably had limited exposure to authentic dialogue during their own educational experiences. It is important to model pedagogical strategies that support authentic dialogue and to create many opportunities for students to engage in planning, teaching, and critiquing lessons that promote authentic dialogue between children.

There is a great responsibility placed on science methods instructors to help students experience the rewards of igniting children's natural curiosity about the world in which they live. Just as children need to engage in authentic dialogue about the concepts they are struggling to understand, and just as methods students need to engage in authentic dialogue about their instructional strategies, their successes, and the struggles they face as beginning teachers, methods instructors need to engage in authentic dialogue with each other about the important task of preparing science teachers for elementary and middle school science classrooms.

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A Performance-Based Approach To Preparing Elementary Science Teachers

Thom A. Votaw

The literature is full of research describing good science teaching; good science teachers, however, have always done these things without benefit of reading the research. Many of us who train science teachers are cognizant of these qualities, from both the literature and exemplary teacher standpoint. Nonetheless, at times we fail to adequately affect teaching behavior so future teachers will reflect exemplary teachers. John Goodlad told us several years ago that teachers tend to teach the way they were taught and that the predominate mode of teaching is teacher talk and individual seat work by students (1984). Good teaching is a complex endeavor; preparing future teachers to have knowledge of and skills in this endeavor is even more complex. What follows is a description of an attempt to break the cycle identified by Goodlad and to lead future science teachers through the complexity of good instruction, with the hope that knowledge gained and behaviors practiced will be permanent.

The Components Of Lessons

In the performance based approach to preparing science teachers, one goal is for seven components of science lessons to be assimilated by students to the extent that the daily use of them becomes automatic. The components for the lessons in order of introducing them to students are:

1. **Motivating strategies** as synthesized by Brophy (1987). Examples of motivating strategies include allowing students opportunities to make choices or autonomous decisions, providing students with opportunities to respond actively, allowing students to create finished products, and providing students opportunities to interact with peers.
2. **Learning styles** as synthesized by Dunn (1990). Dunn identifies four learning styles: auditory, visual, tactual, and kinesthetic.
3. **Levels of mental involvement** from the long-standing work of Bloom, Engelhart, Furst, Hill, & Krathwohl, (1956). Bloom's taxonomy, to which it is commonly referred, contains six levels: knowledge, comprehension, application, analysis, synthesis, and evaluation.
4. **Brain studies** by Caine and Caine (1991) and Williams (1983). The Caines gave us information regarding memory systems and the principles of brain-based learning and Williams gave us information regarding the use of metaphors and fantasy.

5. **Science process skills** by Cleare (1985). Cleare lists observing, using space/time relationships, classifying, using numbers, measuring, communicating, predicting, and inferring.
6. **Creative process skills** by Doutre (1988). Doutre discusses fluency, flexibility, originality, and elaboration.
7. **Integration with other subjects** by several authors. For example, integration with language arts (Fisher & Fisher, 1985); integration with art (Petty, 1985); and integration with math (Goldberg & Wagreich, 1989).

The components of lessons are introduced individually on a week by week basis. Students work in groups to prepare a science lesson and later on teach that lesson to another group. A total of six lessons are prepared and taught, which sets the scene for groups to prepare additional lessons for teaching children in schools. During this entire process, students have several varied encounters with the components of lessons. These encounters indicate repeated exposure and practice in a variety of ways which increase the chances that the components become reflexive teaching behaviors in students' minds. By the end of the class students will encounter all seven components in six ways: the instructor's overview, lesson preparation, teaching of or participating in lessons, assessment and refinement of lessons, feedback, and a final paper and computer disc (see Figure 1).

The first component of a quality science lesson to be introduced is motivation, being perceived as most important. Over the span of six lessons to be prepared, motivation will be part of the preparing and teaching six times. The instructor gives an overview of the component along with a handout describing motivation research (Brophy, 1987). Even though Brophy lists thirty three motivating strategies, students are required to only incorporate three into their lesson. This is the first of six encounters students have with the motivation

		Components Covered in Lessons							Encounters With Components					
		Motivation	Learning Styles	Levels of Mental Involvement	Brain Studies	Science Process Skills	Creative Process Skills	Integration with Other Subjects	Overview	Lesson Preparation	Teaching of or Participating in Lesson	Assessment and Refinement	Feedback	Paper/Disc
Lessons Taught to Peers	1	✓							✓	✓	✓	✓		After teaching lessons in schools
	2	✓	✓						✓	✓	✓	✓		
	3	✓	✓	✓					✓	✓	✓	✓		
	4	✓	✓	✓	✓				✓	✓	✓	✓	✓	
	5	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	
	6	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	

Figure 1. *A synthesis of lessons, components of lessons, and encounters with components, and where they intersect each other.*

component. Students are randomly placed in groups of four. Random grouping continues through lesson five so students get to know one another and can then form their own groups for teaching science lessons in schools.

Rather than listen to an instructor's lecture about motivation, students are challenged to work in teams to learn about motivation and to apply their knowledge in the development of a science lesson. The goal of each group is to prepare a five minute lesson using the component(s) of good lessons. Five minutes may seem very short, but the value in this approach to preparing teachers is to have practice in preparing lessons, to have several encounters with the components of lessons, and to have several experiences in teaching, rather than to teach a single science topic in its entirety. One could even argue that the actual teaching is a mere excuse or a mechanism to facilitate repeated exposure with the components and therefore does not need to be too long. The goal of the entire process is for students to assimilate, to remember, and to use, when they become teachers, components identified with quality science lessons. It is not particularly significant that each and every component incorporated into each lesson be covered completely during the five minute lesson.

Preparing a lesson with peers is the students' second exposure to each component. During this time the instructor's overview is still fresh in their memory. Each time a lesson is prepared the students are provided with a new science subject area. Lessons from *Science and Children* magazine provide examples of the lesson component being studied. The *Science and Children* article on dinosaurs by Fehrenbach, Greer, and Karnes (1989) would be an example of motivation. The lessons students prepare, however, would not be on dinosaurs. In addition, lessons from a hypercard computer data bank of previous students' lessons are made available.

The instructor spends most of his time working with the groups as they prepare their lessons. The time is spent clarifying the ideas concerning the component being studied, brainstorming with the students about the lesson they are preparing, generally communicating ideas about instruction, and modeling the behavior of facilitating the process of learning.

The brief overview of the component and the initial preparation of the lesson takes place during a single class session. Typically, students will have to meet out of class to continue to work on their lessons; they are reminded that this out of class preparation time is "homework." Each group comes to the next class with its lesson ready to be taught. The lesson reflects the ideas about motivation as the first component to be studied.

Peer Teaching Using The Components

Three members of the four member group which prepared the lesson will get the opportunity to teach their lesson to another group of students in a round-robin situation. Assume there are four groups (A, B, C, D) of four students (1, 2, 3, 4) each. An initial "teacher," who we designate as "1," is selected from group "A." The remaining three students (2, 3, 4) move to group "B" to be taught a lesson by

that group's teacher "1." The three students from group "B" move to group "C" to be taught a lesson by group "C's" teacher "1." The three students from group "C" move to group "D" to be taught a lesson by group D's" teacher "1." The three students from group "D" move to group "A" to be taught a lesson by that teacher "1."

When the initial teachers have students, their five minute lessons are taught, in the first case, stressing the component motivation. This is the third encounter with the component motivation, both from the initial teacher's perspective and their students' perspectives.

After the lesson, the students return to their original group. At this time the initial teachers provide information to their peer group regarding how the teaching of the lesson fared. Particular attention is given to the degree of success regarding the component motivation. Thus, motivation is considered a fourth time as the lesson is assessed and refined.

Another teacher, "Teacher 2," is selected from each group. The student population now consists of students 1,3, and 4. During this second round of teaching, these students move to a different teacher and lesson than they encountered before. The students from group "A" move to teacher "C" so they will not get the same lesson twice. Students from "B" move to teacher "D," those from "C" move to teacher "A" and those from "D" move to teacher "B."

The lessons are taught a second time by different teachers to different students. The students again return to their own groups to discuss the degree of success of the teaching of their own lesson by their own teacher. A third teacher is selected from each group and each teaches his or her lesson to another group of students. The teacher from group "A" teaches students from group "B," the teacher from group "B" teaches students from group "C," the teacher from group "C" teaches students from group "D," and the teacher from group "D" teaches students from group "A."

The lessons prepared are taught three times by three different teachers to three different groups of students. One person from each group did not get to teach this particular lesson but since a total of six lessons will be taught he or she will have ample opportunity to teach.

Learning styles, the second component of quality science lessons, is briefly discussed during the next class. Research articles (Dunn, 1990) and exemplary articles from *Science and Children* (see, for example, Kahane and Jackson, 1988) are handed out, computer data bank lessons are made available, new random groups are formed, a new science topic is chosen, and the students again prepare a five minute lesson to teach. The lesson is to contain the new information regarding learning styles plus previous information regarding motivation. During the next class this lesson is taught three times by three different teachers in the same way the first lesson was taught.

This process of introducing a new component, preparing, and teaching lessons continues sequentially for six weeks, adding a new component each week. Six lessons covering the seven components are prepared and taught. Each lesson contains the current component being introduced plus all the previous ones. That

is, lesson number one only contains motivation. Lesson two contains the new component of learning styles plus the previous component of motivation. This additive process continues until the sixth lesson contains all seven components: motivation, learning styles, levels of mental involvement, brain studies, science process skills, creative process skills, and integration of science with other subjects. The latter two are implemented together.

Lessons one through three are only five minute lessons. Trying to implement three lesson components into a five minute lesson is difficult for the students. However, they seem to be able to accomplish this to a fair degree. As mentioned earlier, the value of this teaching model does not lie with a single lesson covering several components to a high degree but rather by repeatedly encountering the lesson components in a variety of ways.

Lessons four, five, and six become ten minute lessons, thus permitting additional time for more components. Members of the "student" group jointly complete a feedback sheet for the teacher who just taught the lesson. After the completion of the form the components are once again discussed. The teacher who taught the lesson receives the feedback sheet and has this information regarding how others perceive his or her success at teaching the lesson and using the components.

Lesson six differs from the format of lessons four and five in that self-evaluation replaces peer feedback. Up until now groups have been formed randomly, thereby permitting students to get to know each other. In lesson six random grouping of students is replaced by students selecting their own members. This is done in preparation for teaching lessons in schools where students will need to be able to be part of a compatible group.

Lessons Taught In Schools

After preparing and teaching the six lessons on campus to peers, groups of three or four students are formed and these groups prepare and teach three lessons in schools to children. This process draws on all the experience gained by preparing and teaching lessons on campus and generalizes it to a more realistic situation. During the process of preparing these lessons for schools, the components are once again part of the thinking and planning. Actually teaching these lessons to children is the real test of the validity of the performance based model.

The three lessons are taught in schools during regular school class time. One lesson is taught each week for a period of three weeks. Students have their choice of either teaching a single lesson to three different elementary classes or teaching a three lesson unit to a single elementary class There is ample time between the teaching of the lessons for assessment and refinement, something practiced when lessons were being taught to peers. Students utilize all seven components in their teaching; the content area comes from the school's curriculum guide. A feeling of confidence during this experience is typical among students because of all the practice at the university.

The culminating activity for the lessons taught in schools is the submission of a written lesson plan, either the single lesson or the three lesson unit, along with a computer disc containing the lesson plan. The lessons contain the modifications made between visits to schools. The lesson on the disc is added to an existing hypercard science lesson data bank for use by students in subsequent semesters. Students in turn receive a computer copy of the entire set of lessons from their own class and previous classes.

As students gain familiarity with the components of quality lessons and practice using them, they are performing the complex act of teaching—the desired outcome of teacher training. During the course of preparing and teaching six science lessons to peers and three science lessons to children, students have become familiar with and have used seven components identified with good science lessons.

Conclusion

The model described in this article centers around seven components of lessons being introduced in an additive fashion with students preparing and teaching lessons that incorporate the components. Students encounter the components in different ways, thus increasing the likelihood of their remembering and using them. While many other things take place in the class during the semester, providing students with the opportunity to grapple with what makes a good lesson is of primary importance.

This performanced based model for preparing science teachers has gone through several revisions over the years and former students who are now practicing teachers continue to relay the value they perceive in this approach. We believe the model utilizes descriptions of good science teaching and what good science teachers have always done. The basic concept appears sound with fine-tuning continuing each semester.

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The Science Activity Filter: Guidelines for Improving the Selection of Science Activities

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New teachers are thrust into a role that is full of demands, challenges, and unknowns. Beginning teachers must learn school rules and procedures; they need to decide what to teach and how to teach it; and they need to learn about their students and how to work effectively with them. Teaching science has the added challenges of finding or creating science activities, acquiring and organizing the necessary materials, arranging the materials for the lab stations, and transitioning in and out of science activities (Latz, 1992).

As the effectiveness of a hands-on, minds-on approach is increasingly recognized, teachers are being advised to expand their use of this experiential method. The National Science Teachers Association (NSTA) advises preschool and elementary level teachers to use a minimum of 60% of science instructional time for hands-on activities (NSTA, 1990). Middle school teachers are advised to spend a minimum of 80% of science instruction time on laboratory-related experiences that involve hands-on activities (NSTA, 1990).

The number of published science activities is large (Bosak, 1991). These activities can be found in sourcebooks, activity books, textbooks, teacher resource books, and journals. Over a decade ago, Pines and Pines described the market as "glutted with teacher handbooks, as seen on every publisher's stand at every annual teachers' convention, at administrative conferences, and winking at us in our daily mail" (1981, p. 16). For the period from January 1982 to September 1993, the ERIC database contained 1883 abstracts for documents, books, and journal articles with the descriptor "science activities," "science experiments," or "science projects," appropriate for students in elementary and middle school grades. The numerous science activities have the potential to be valuable resources for teachers. However, the volume "can be overwhelming. It can also be intimidating to someone who is hesitant about guiding children in science experiences" (Bosak, 1991, p. 2).

Adding to the confusion is the problem that not all of the quantity is quality. After analyzing 50 pre-secondary science activities from a variety of authors and publishers, Anderson, Beck, and West concluded, "The quality of most activities accessible to teachers is rather poor" (1992, p. 17). Some published activities can

also be dangerous. Manning and Newman (1986) found serious safety problems in activities suggested in some sourcebooks.

The effectiveness of an activity is highly context dependent. Activities may be effective in some environments but still not be appropriate for a particular classroom, time schedule, or school budget. Well designed activities can be misused by teachers, for example, when teachers present a series of unconnected activities that fail to develop conceptual foundations of knowledge (Pines & Pines, 1981).

Beginning teachers can run into difficulty because they may not have the experience and knowledge base to select effective activities. Two teachers' descriptions of their start in teaching illustrate this problem: "I basically was left to fend for myself and I just happened to survive" and "I learned from trial and error" (Pankratius & Snow, 1990, p. 20). While trial-and-error learning may produce some unforgettable moments, it can be an inefficient and frustrating way to learn. Using inappropriate science activities may waste student and teacher time, squandor resources, induce frustration, catalyze discipline problems, and even create danger for the students.

In time, teachers develop pedagogical content knowledge—the product of the interaction of a teacher's content knowledge and effective teaching strategies—which includes a knowledge of how and when to use teaching materials to help students acquire skills and concepts (Clermont, Krajcik, & Borko, 1993). Experienced teachers develop a "feel" for determining which activities will work. "Exemplary educators cull activities from a wide range of sources and incorporate them daily into their lessons to improve instruction" (Beisenherz, 1993, p. 22).

Preservice teachers need help in learning how to efficiently and effectively choose good science activities. Teacher educators may have developed an intuitive sensitivity for knowing which science activities will work, and they may forget that preservice teachers need help in developing this skill. Teaching and learning how to choose good science activities can seem difficult because there are few absolutes. Activities appropriate for one class may be inappropriate for another; one teacher may love activities that another scorns. Preservice teachers need to be exposed to effective science activities (Tilgner, 1990), and they need to know why these activities are effective. They also need to be exposed to ineffective activities and need to be enabled to determine why these activities are ineffective.

In response to this need we developed a set of practical, realistic guidelines to help teachers of all grade levels choose science activities. The guidelines were developed from (a) our experiences teaching science and prospective teachers of science, (b) field testing science activities for a national publisher, (c) the educational literature, (d) interviews with preservice teachers and science teachers, and (e) discussions with science teacher educators. The guidelines are not absolute but serve as a model for teachers who are creating their own guidelines (see Figure 1). We call our guidelines the Science Activity Filter

because the guidelines can help teachers choose appropriate activities from the abundance of existing science activities.

Activities that do not pass all of the guidelines can be rejected or modified. Learning to make modifications is important in order for the teacher to produce a better match between the selected activity, the students, and the desired learning outcomes. "Hands-on activities [at the elementary level] should be revised and adapted to meet student needs and to enhance curricular goals and objectives" (NSTA, 1990, p. 1). "Teachers are also expected to adapt materials for students of differing abilities and those with physical or emotional handicaps" (Stefanich, 1992, p. 14).

When introducing the Filter in education methods classes, we ask the class to brainstorm a list of factors they would consider in choosing a science activity for possible classroom use. After an extensive list is generated, items are grouped

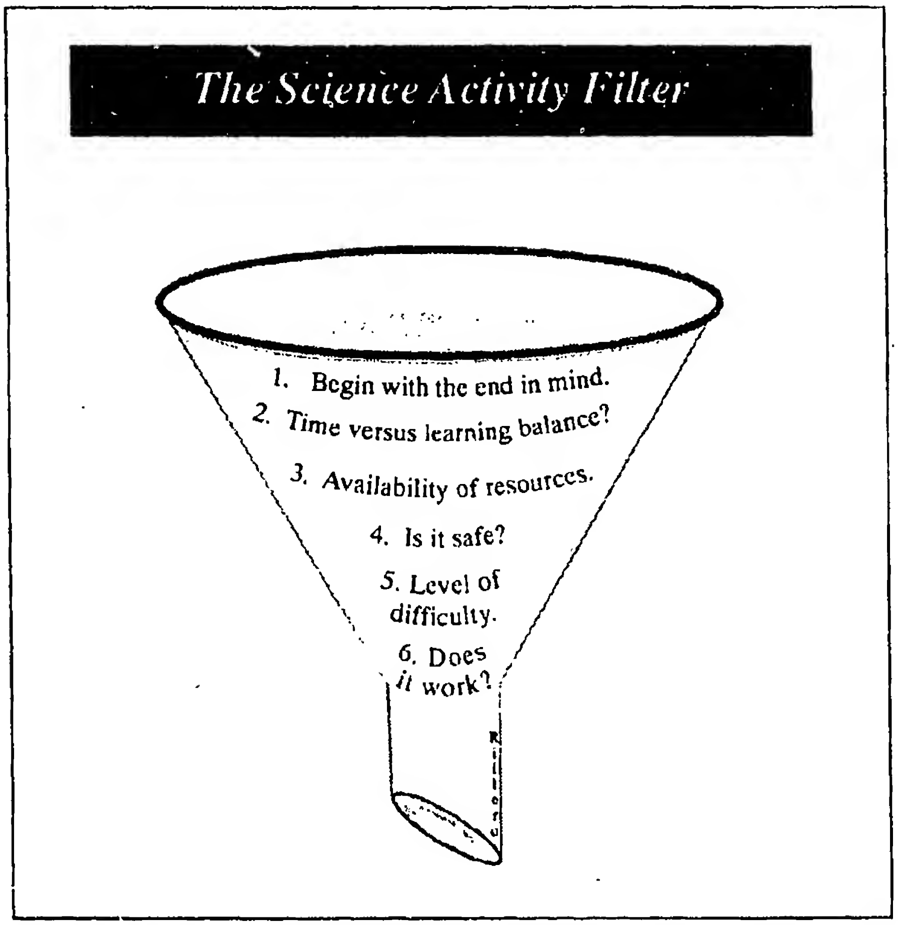

Figure 1. The guidelines of the Science Activity Filter. The order of the guidelines presents a useful protocol for evaluating science activities for potential use in a classroom.

into categories that are similar to the Filter's guidelines. We present and explain the Science Activity Filter to the students, and discuss activities that did and did not pass the Filter's guidelines. Activities presented to preservice teachers should be appropriate for the grade level they will teach. The Filter is appropriate for use by teachers at all academic levels; however, in this article we explain the guidelines of the Filter and illustrate their use with activities designed for elementary and middle school children.

Begin With The End in Mind

Covey (1989), in his book *The 7 Habits of Highly Effective People*, suggests that to lead an effective life you must "begin with the end in mind." Beginning with the end in mind means having a clear picture of your destination. By knowing where you want to go, you can tell where you are now, so the steps you take will always be in the correct direction.

> If the ladder is not leaning against the right wall, every step we take just gets us to the wrong place faster. We may be very busy, we may be very *efficient*, but we will also be truly *effective* only when we begin with the end in mind. (Covey, 1989, p. 98)

Educators agree that beginning with the end in mind is certainly important for selecting effective science activities. "Exemplary teachers have a vision of what they want their science program to be and what they want their students to accomplish" (Beisenherz, 1993, p. 24). "If you set out to design the best possible elementary school science program, what will you include in your plans?... First, determine what you expect of the program and the students. Doing so requires written goals and objectives" (Orlich, 1985, p. 10). "Teachers must first make decisions about which concepts and processes to teach—and then seek ways for imparting these in some meaningful fashion" (Pines & Pines, 1981, p. 18).

There are many reasons, objectives, and goals for science education and science experiences. For example, the Committee on Science Education for the National Assessment of Educational Progress has developed the following objectives for students in science:

1. Know[s] fundamental facts and principles of science.
2. Possesses the abilities and skills needed to engage in the process of science.
3. Understands the investigative nature of science.
4. Ha[s] attitudes about and appreciations of scientists, science, and the consequences of science that stem from adequate understanding. (Williamson, 1977, p. 11)

The NSTA position statement on laboratory science (1990) recommends that laboratory activities enhance student performance in the following domains: process skills, analytical skills, communication skills, and conceptualization of scientific phenomena. Johnson, Laughran, Tamppari, and Thomas (1991) indicate that middle school science activities should help the student to (a)

develop or modify his or her understanding of a significant science concept, (b) practice process skills, (c) use quantitative thinking, (d) integrate science subjects, (e) utilize an inquiry approach, and (f) experience success and build self-confidence.

From these lists and others, we have developed three categories of potential outcomes associated with doing science activities: (a) conceptualization of scientific phenomena, (b) science process skills, and (c) student attitudes.

Conceptualization of Scientific Phenomena

The conceptualization of scientific phenomena is a learning outcome of science activities that focuses on understanding science content (Johnson, Laughran, Tamppari, & Thomas, 1991; NSTA, 1990; Williamson, 1972). Constructivist ideas can guide a teacher in deciding if an activity is appropriate. Instruction should take into account what the student already knows. "Children learn more readily and remember things longer when they can connect new experiences and information with that they already know about the world—in other words, when they can actively construct their own knowledge" (Kober, 1993, p. 6). "Using situations or materials familiar to the young adolescent will allow the student to more readily assimilate the new information into his or her existing body of knowledge" (Johnson, Laughran, Tamppari, & Thomas, 1991, p. 81). At the preschool/elementary level "activities should be selected that allow students to discover and construct science concepts; and, after the concept is labeled and developed, activities should allow for application of the concept to the real lives of students" (NSTA, 1990, p. 1).

The use of the learning cycle is an effective approach for helping students conceptualize science. Meichtry (1992) presents effective learning cycle activities for teaching concepts related to stream study. Through three phases—concept exploration, concept introduction, and concept application—students interact with materials to simulate stream beds, record observations, participate in class discussions, learn concepts and terminology, and then apply the concepts in further activities. This approach sequences science activities from "concrete to abstract and provides opportunities for students to be actively involved in inquiry-based activities.... The learning cycle approach is particularly effective at the middle school level as it is well-suited to the developmental characteristics of young adolescents" (Meichtry, 1992, p. 437).

Meichtry's approach provides an example of using activities effectively to help students develop conceptualizations of scientific phenomena. The activities match the intended learning outcomes. In contrast, Zeitler and Barufaldi (1988) provide the following example of an inappropriately chosen science activity in grade 3. "Children were studying factors that affected seed germination. During this lesson they were asked to root a cutting from a coleus plant" (p. 147). The activity is considered inappropriate because "the lesson deals with germination of seeds rather than producing new plants from cuttings" (p. 148).

Lack of conceptual focus can weaken science activities. In the activity "Silly Putty Pickups," the challenge as stated is "students will explore the properties of Silly Putty™ and the types of print and picture books [*sic*] that can be picked up by Silly Putty™" (Runyan, Dowd, & Sarquis, 1993, p. 62). Students press Silly Putty™ on printed materials to see if the color gets picked up. The only direction for the second focus of the challenge is to "allow students 10-20 minutes to examine the properties of Silly Putty" (p. 63). Finally, the teacher is to demonstrate that if Silly Putty™ is pulled slowly it stretches and if pulled quickly it snaps back. The assessment of the activity is to "ask students to list reasons for calling Silly Putty™ a solid and reasons for calling Silly Putty™ a liquid" (p. 63). While this activity may be useful in some exploration situations, the conceptual objectives of this activity are unclear, the procedure is vague, and the assessment seems only remotely connected to the challenge statement or the procedure.

It is important to be aware of the potential of an activity to produce or reinforce misconceptions. Perhaps when some nonexperimental science activities are called experiments, students gain an inaccurate understanding of what an experiment really is (Eccles, 1963). Some experiments used in classrooms do not really substantiate the theories they are said to prove (Hershey, 1992). Science activity books may continue to publish activities designed to prove a theory that is no longer accepted by the science community. For example, hydrotropism experiments are a common elementary science activity; however, the existence of hydrotropism is seriously questioned by most botanists (Hershey, 1992).

Science Process Skill Learning

Process skill learning is an important outcome of science experiences (Johnson, Laughran, Tamppari, & Thomas, 1991; NSTA, 1990; Rutherford & Ahlgren, 1990; Williamson, 1972). "The process component of science is an integral part of all elementary science programs which involve students in hands-on type activities" (Brown, 1974, p. 97). "Many scientists and educators now feel that teaching process skills is more important than teaching the details of science" (Johnson, Laughran, Tamppari, & Thomas, 1991, p 80).

In *Science —A Process Approach* (AAAS, 1968), the basic process skills associated with science are listed as follows: observing, classifying, using space/time relationships, using numbers, communicating, measuring, inferring, and predicting. The basic process skills provide a foundation for the higher integrated process skills of formulating hypotheses, controlling variables, interpreting data, defining operationally, and experimenting (AAAS, 1968).

Activities for learning science content can also help students learn science process skills. For example, in the previously described learning cycle activities for concepts related to streams (Meichtry, 1992), the process skills of observing, communicating, measuring, inferring, and interpreting data would be used by students conducting the activities. However, it should not be assumed that because students are doing hands-on science, they are acquiring all of the needed process skills.

> Most lab activities that verify content do not systematically provide instruction on either the process skills of science or on the components of experimental design and data analysis. Repeated trials, for instance, are not frequently found in lab activities, because repetition takes too much class time and is not very exciting. It is no wonder that one of the most common flaws in science projects is the lack of repeated trials. (Cothron, Giese, & Rezba, 1993, p. 167)

From an analysis of science activities in junior high school textbooks and supplementary materials, Pizzini, Shepardson, and Abell (1991) concluded that students have little opportunity to identify or formulate problems or hypotheses, design investigations, and communicate about their investigations. Including open-ended inquiry activities in their repertoire of science activities may help students develop these skills. Educational research on biology laboratories covering the last 20 years indicates that open-ended laboratories are better at teaching laboratory techniques, process skills, and biological concepts, than are approaches in which the student is simply following procedures and making observations (Leonard & Penick, 1993).

Student Attitudes

Beyond developing conceptualizations of science and science process skills, science experiences should contribute to the development of positive feelings toward science and scientific attitudes (Johnson, Laughran, Tamppari, & Thomas, 1991; Loucks-Horsley et al., 1990; Rutherford & Ahlgren, 1990; Williamson, 1972). The term "attitudes toward science" refers to how students feel about science and how they feel about learning it. Scientific attitudes are approaches toward understanding the world.

Attitudes toward science are important because they may influence students' achievement in science and students' willingness to pursue science careers (Johnson, 1979).

> Elementary school children also need to develop positive attitudes toward science and toward themselves. Good elementary science programs strive to help children maintain or develop a sense of awe, curiosity, creativity, and the use of scientific resources to develop explanations about the natural world. Figuring out what it takes for plants to grow, lighting a light bulb and determining why it works one way and not another—these successes, so unlike many outcomes of schoolwork, should make children feel good about gaining more control over their world. (Loucks-Horsley et al., 1990, p. 42)

Student perception about the importance of science is consistently correlated with a student's attitude towards it (Haladyna, Olsen, & Shaughnessy, 1983). Science activities which help a student see the use and value of science may help improve students' attitudes toward science. The Science/Technology/Society approach may be useful in building positive attitudes because it focuses on

problems which students have identified and in which they have some personal stake (Yager, 1993).

Scientific attitude may be related to attitude toward science, but it is different. Scientific attitude has been defined as "the willingness to wait for a conclusive answer—the skepticism that requires intellectual restraint and the maintenance of doubt.... the attitude of intelligent caution, the restraint of commitment, the belief that difficult problems are always susceptible to scientific analysis, 'and the courage to maintain doubt" (AAAS, 1968, p. 2). Loucks-Horsley et al. (1990) list the characteristics of a scientific attitude as desiring knowledge, being skeptical, relying on data, accepting ambiguity, being willing to modify explanations, cooperating in answering questions and solving problems, respecting reason, and being honest.

Values, attitudes, and skills make up what Rutherford and Ahlgren (1990) call the "habits of mind." "They all relate directly to a person's outlook on knowledge and learning and ways of thinking and acting" (Rutherford & Ahlgren, 1990, p. 172). Helping students gain science process skills, improve attitudes toward science, develop scientific attitudes, and learn conceptualization of science need not be considered as separate goals of a science program or a science activity; however, they are all outcomes associated with effective science programs striving to help make students scientifically literate (Cothron, Giese, & Rezba, 1993). By "beginning with the end in mind" the teacher can evaluate activities before, during, and after completion to determine their effectiveness.

Is the Learning in Balance With the Time Spent?

When teachers have found activities that appear to meet their learning objectives, they should analyze these activities using additional criteria. This second guideline of the Science Activity Filter focuses on whether the time consumed is in proportion to the potential outcomes. This is an important consideration because time in and around the classroom is limited (Donivan, 1993; Ellis & Kuerbis, 1992; Foster & Dirks, 1993; Morey, 1990; Rutherford, 1993; Teters & Gabel, 1984; Tilgner, 1990). There are two aspects of time consumed by an activity that should be evaluated: (a) How much classroom time will be spent on the activity? and (b) How much time will it take for the teacher to prepare for the activity? While each aspect is evaluated, the overall question should be kept in mind: Is the time consumed in balance with the value of the learning experience?

In examining an activity, it is important to determine whether it is worth the classroom time devoted to it. An activity may have the desired learning outcomes, but it may not fit into available classroom time. One activity suggests building a model space shuttle (Vogt, 1991). The children fashion the frame from the following simple materials: egg cartons, plastic bottles, tape, and glue. They cover this frame with paper-maché and paint it to resemble the shuttle. Elementary school students in a Montessori class took more than four hours to assemble the shuttle. This project may be worthwhile, for example, in introducing a unit

on rocketry. However, we judged this activity to be inappropriate based on the large amount of classroom time used. Since the amount of time devoted to science at the elementary level is limited (Tilgner, 1990), it is very important that the time be well spent.

Teachers' time outside of the class is also limited, and for new teachers the time crunch can be especially severe. Johnson, Laughran, Tamppari, and Thomas (1991) assert that "neither the time nor the energy is available to develop or even locate the science activities that can allow the first year teacher to focus on the learning of science by individual students" (p. 79). Perhaps this assertion is overstated; nevertheless, it is important to consider how much teacher time is needed to prepare for an activity.

Assembling the materials and equipment for science activities can take a great deal of time. It took Anderson, Beck, and West (1992) 40 minutes to set up a middle school science activity, and they were working from a well stocked lab room. Their assembly of materials was difficult because the materials list did not identify some needed equipment (scissors, stirring rod, scales, tasting rod) and did not specify sizes for the listed lab apparatus (beakers, flasks, 1-hole stoppers). Construction of equipment for activities may increase the time required for preparation. For a spider web activity for middle school students (Beck, 1992), a teacher would need to purchase materials and construct a web board for each group doing the activity. Plywood boards cut into 0.75x0.8m sheets would have to be ordered or cut by the teacher. Each sheet would be painted dark blue, and 153 finishing nails hammered in at specific points. We encourage teachers to spend the time finding, developing, and preparing science activities, yet we also encourage teachers to find a comfortable balance of time used in relation to student learning outcomes.

Availability of Resources

A lack of facilities, materials, and equipment, and the money to buy them, is a major obstacle for teaching hands-on science that can rule out the use of some science activities (Foster & Dirks, 1993; Haury & Rillero, 1992; Helgeson, Blosser, & Howe, 1977; James & Hord, 1990; Morey, 1990; Pankratius & Snow, 1991; Teters & Gabel, 1984; Tilgner, 1990; Williamson, 1972). Many presecondary teachers who want to do activities do not have access to a laboratory or adequate facilities in their classrooms. If an activity requires the use of facilities such as sinks, electrical outlets, windows that receive sun, or fume hoods, and the required facilities are not available, either modifications in the procedure will have to be made, or the activities cannot be done.

Equipment and materials required for an activity must also be considered before selecting an activity. Are the equipment and materials present in the school? The materials list for one elementary activity is as follows: Apple IIe, II+, or IIc; Science Toolkit™: Master Module; Science Toolkit ™: Module 1 Speed and Motion; software disks for both modules; interface box; 2 photocells (one comes with each module); balloons; toy car (comes with module 1); speed

trap (comes with Module 1); light source (flashlights); ruler or meter stick; string; masking tape; graph paper (optional); notebook or paper; and other types of small cars (Woerner, 1993). Most schools would not have the required modules and software on hand. Even if the school was willing to buy the equipment and software, it would probably not be prudent to purchase it just for this one activity. The purchase might be worthwhile if it was determined that the materials could be used in other effective science activities.

Anderson et al. (1970) advise teachers to make a list of all necessary equipment and to check that list against available equipment. When teachers are requesting that equipment be bought by the school, they should prioritize the items requested based upon the projected activities. An effective way to do this is to consider the expense for the items needed in an activity in relation to the learning outcomes. Optimization of resources is important for learning experiences. If materials, equipment, or facilities are not available, it may be impossible to do certain science activities. However, this should not be an excuse for avoiding hands-on science. Many effective science activities and activity programs use readily available materials.

Is the Activity Safe?

The issue of safety, the focus of the fourth guideline of the Science Activity Filter, should rule out some science activities. Modern publications—thanks in part to advances in science and a litigious society—are presenting safer activities. Care should be used in selecting activities from older publications (Manning & Newman, 1986). An activity commonly included in older sourcebooks is making a longitudinal section of a battery to investigate what is inside. Doing this with a nickel-cadmium battery can be dangerous because its high discharge rate can cause severe burns. Furthermore, cadmium is a highly toxic substance (Manning & Newman, 1986).

Activities that use hazardous materials need to be avoided. Older sourcebooks may contain activities with instructions for students to handle hazardous materials such as benzene and carbon tetrachloride (Manning & Newman, 1986). As acceptable levels of exposure to some materials are lowered, even newer sources of activities may utilize materials considered to be hazardous. The Chemical Manufacturers Association has a service called Chemtrec; by dialing 1-800-262-8200 teachers can either get referrals or information sheets on chemicals that are of concern.

Anderson, Beck, & West (1992) identify safety problems with the sequencing of directions in an activity. A water cycle activity in a middle school earth science textbook has inappropriate sequencing in several steps.

2. Carefully taste the solution.
3. CAUTION: Be sure the glassware is clean....
6. Insert a small piece of glass tubing through a one-hole rubber stopper.
7. *CAUTION: Use glycerine and a towel to insert the tubing.* (pp. 4-5)

Unfortunately, the cautions in steps three and seven are presented after the students may have already performed the actions they are being cautioned about.

Other aspects related to safety concerns are the number and type of the students involved, the facilities available, and the knowledge and comfort level of the teacher in working with potentially dangerous materials. Specialized considerations and sources of information on aspects of laboratory safety include safe science for students with disabilities (Bazler & Roberts, 1993), safety despite time constraints (DeCoster, 1992), toxicity of substances (Crellin, 1989), and a safety manual for elementary science (New Jersey State Department of Education, 1986).

Level of Difficulty

Good science activities challenge students, and they give students the opportunity for success. For activities to be effective they must be at the proper level of difficulty. If an activity is too easy, it will be boring; if it is too difficult, it will induce frustration. If an activity is too tedious, it may become both boring and frustrating.

Before choosing to do an activity, it is important to know if the students have the manipulative and process skills that are required. Will the students be able to accurately use scientific apparatus, create a data table, or plot a graph? If not, preliminary activities may be needed to introduce the necessary skills to the students.

Written instructions and explanations are important in many science activities. "A clear statement of the problem or task, together with some underlying rationale, must always be provided" (Hawkey, 1993, p. 113). By necessity, many steps in protocols are implicit rather than explicit. Sometimes these implicit steps can cause confusion.

> When designing and writing science activities, the author must decide which procedures must be explicit and which can be left tacit or implicit as a subroutine. For example, students in the sixth grade are likely to know what it means to "cover the dish pan," but may not know what it means to "CAREFULLY taste the solution." (Anderson, Beck, & West, 1992, p. 13)

Thus, it is important to ask: Is enough detail presented in the protocol to do the activity? Illustrations and pictures can not only make an activity more interesting but also help students in understanding protocols and explanations.

Hawkey (1993) identifies the presentation of information as another important part of a science activity. "At best, workcards/worksheets give sufficient detail for the task; at worst, the material may become laden with inessential terminology or facts. Inappropriate or irrelevant information may actually hinder the learner, hiding the essence of the task" (Hawkey, 1993, p. 113). The questions asked in a science activity are important; they should promote high levels of

thinking. Questions "most helpful to learning may reflect on the scientific process or raise awareness of key issues.... The least productive questions may simply reinforce the obvious or give inappropriate emphasis to lesser elements of the activity" (Hawkey, 1993, p. 113). The readability of the activity can influence many aspects of its level of difficulty. The lengths of words, sentences, and the use of unknown vocabulary influence the level of difficulty in the reading. Layout influences more than the aesthetic appeal of the activity; it can make the text easier to read (Hawkey, 1993).

Does It Work?

Finding activities that don't work is not uncommon. It would be nice if all authors and publishers tried out all activities before printing them, but this is apparently not the case. One activity from a sourcebook says to use a lemon, copper wires, a steel paper clip, and a brass pin to light a 1.5 volt light bulb (Kent & Ward, 1986). Despite numerous placements of the electrodes and attempts with different lemons we could not get a 1.5 volt light bulb to light. Anderson, Beck, and West (1992) could not follow the procedures of another published activity because the volume of water collected from a condensation apparatus was much too small to measure.

It can be difficult to read an activity and know if it will work. Although doing so uses a teacher's time, all activities should be tried before they are used in a classroom. Only activities which have passed through all the previous layers of the Science Activity Filter should be tried. By following the sequence of the guidelines, teachers reduce the number of activities they should try (as is symbolized by the narrowing of the Science Activity Filter's funnel in Figure 1); this optimizes teacher time and resources.

Doing activities before using them in class also checks the efficacy of the materials. Chemical reagents and batteries can lose their potency. In an analysis of the Science Curriculum Improvement Study II program, major problems reported by teachers are typified by the following description of problems with the Population unit:

> Seeds are planted, but few germinate. The crickets arrive with little to eat, so they immediately begin dying. Meanwhile, the few spindly plants that have grown are pressing against the aquarium lid, which fits poorly, and may even be cracked near the fastening points. Once the lid pops up, the remaining crickets start to disappear from the terrarium. (Atwood & Howard, 1990, p. 855)

An added benefit of trying out activities is that teachers can re-evaluate the activities based on the previous Science Actvity Filter guidelines as they conduct the activity. Zeitler and Barufaldi offer the following advice to elementary school teachers:

One method for determining the effectiveness of an activity is to try it yourself before writing it into a unit or using it with your students. Having done an activity yourself, you are better prepared to help students work through the activity and learn from it. In addition, doing the activity can help you identify prerequisite skills and knowledge required of learners. (1988, p. 170)

Final Thoughts

In our interviews with elementary school preservice teachers before presenting the Science Activity Filter, no individual suggested considerations that reflected all of the Filter's guidelines. In fact, most of these prospective teachers could name only a few things they would consider in choosing a science activity. During our presentations of the Filter, however, each class brainstormed a long list that reflected all the Filter guidelines. The Filter is a simple and time efficient manner for getting prospective teachers to think a little more broadly about factors to be considered in choosing effective science activities.

The Science Activity Filter is not a static system, but one that can evolve with the experience and sophistication of a teacher. The first guideline, "begin with the end in mind," challenges teachers to choose educational outcomes. These outcomes may change as the teacher matures, and outcomes can be different for certain students and situations. After becoming familiar with the Filter's guidelines, teachers may wish to create their own set of guidelines. Helping preservice teachers develop realistic guidelines for selecting activities is an important step in helping teachers use a hands-on, minds-on approach to teaching science.

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Educating Science Teachers Through Action Research

Dale G. Merkle

Encountering preservice and inservice students term after term gives one much food for thought concerning some of the problems of teaching elementary school teachers to teach. One of the postulates that has sifted down from Educational Psychology is that activity on the part of the learner is preferred to passivity. Considerable literature (Ausubel, D., Novak, J., & Hanesian, H., 1978; Bruner, 1960; Gagne, 1977; Good, T. & Brophy J., 1987; Resnick, 1983) attests to this premise. A plethora of science educators (Lawson, A. et al, 1989; Lindberg, D., 1990; Morris, C., 1990; Selim, M. & Shrigley, R., 1983) have advocated the activity approach, and recent text series and new and old national curricula reflect this point of view, particularly the elementary science education curricula. The strength of these ideas abides in the research.

In the author's science education courses activity-based learning is a regular feature. Students have come to expect that, no matter what the academic focus, some hands-on, minds-on activity will be used to stimulate their critical thinking about the topic. Students are often guided through a number of activities which give them a look at science curricula, in general, and how children construct their own learning, in particular. The students create teaching units using the constructivist approach and the inclusion of hands-on/minds-on activities is one of the requirements for this unit. Old programs, such as *Science-A Process Approach* (American Association for the Advancement of Science, 1967), *Science Curriculum Improvement Study* (Karplus & Thier, 1970), and *Elementary Science Study* (Elementary Science Study, 1976) are made available for students to review along with *Activities for Integrating Mathematics and Science* (Project AIMS, 1987), *Science Activities for the Visually Impaired / Science Enrichment for Learners with Physical Handicaps* (SAVI/SELPH Program, 1981) and others. The course outline for science methods states that, " teachers cannot be interested in that which is unknown to them," and "commitment to the active use of tasks in the classroom is essential."

However, doing hands-on activities and telling students that this is how children learn best has not proven to be an effective strategy for getting students to look into their pedagogy and determine what is effective instruction and what is not.

In science education courses for pre-service and in-service teachers it is emphasized that their work in the classroom has two primary objectives: (1) to help children learn, and, (2) to help children retain what they have learned. Talking and reading about better methods to teach elementary school science, however, is no guarantee that students will apply these techniques in their

classrooms when they teach. This problem gave birth to the idea of doing action research with the methods students. Why not use two different approaches to teaching the same topic and determine which is better?

The goal was to involve students as subjects in action research to motivate them to consider how pedagogy impacts on teaching effectiveness, and, to encourage them to use action research with their school children. Action research, while limited in its generalizability, can provide teachers with a foundation for selecting effective teaching strategies.

The action research described here is a simple attempt to involve science education students in a test of two methods of learning. The students are the subjects. One of the goals of this activity is that having research applied to the students themselves will provide a positive example for their understanding of the educational advantages of using hands-on, critical thinking activities to teach science to children. Another is that they might cognitively recognize the benefits that can be derived by doing research themselves.

The research question for this activity is: Does participation in an inquiry activity promote better learning and retention than a reading activity when learning some simple concepts concerning the pendulum?

Prior to the first session the names on the class lists are randomly divided into two groups of approximately the same size. A short pretest on basic pendulum concepts is given in the first week of class. The test includes questions about how certain variables affect the period of a pendulum. No preparation time is allowed, nor is an explanatory lecture given. The classes are then divided into the two groups. One group is directed to use the texts and references on reserve in the curriculum library for about one hour. Several middle-level physical science books, which include pendulum information, are among the references available for the students. The other group remains in the classroom and uses the materials from the *Elementary Science Study* (1976) unit on pendulums to investigate the problems proposed in the examination. They complete the activities on the effects of changes in mass, size of arc, and length of string, then organize their data and analyze the results of their inquiry without teacher direction.

When both groups are back in the classroom a post-test is given. The pretest and post-test are identical. In the next class session the results of the test data are shared with the students. The postulate that "activity on the part of the learner is preferred to passivity" is discussed. Students are almost always surprised with the results.. Their success with the "book" approach in the past has made them confident of that method. However, the results of this one action research is often enough to convince them that "doing" is better than "reading." The class also discusses the simple steps of completing action research.

No further reference to these tests or the pendulum activity is made during the next several weeks of the semester. In the next to last session of the class a post-posttest is given to secure data regarding their retention of knowledge concerning pendulums. These data and the relationship of this new data to the results of previous testing are discussed.

The pretest, posttest, post-posttest sequence has always provided convincing data in regards to the research question. The two comparisons, one for learning (pretest to posttest) and one for retention (posttest to post-posttest), usually indicate a significant difference in the scores for the two groups. The activity group regularly achieves significantly higher than the reading group on both of these comparisons when data are analyzed using a t test. A pretest comparison usually indicates no significant difference between the two groups on the pendulum test prior to the treatment. When the data from the whole study is discussed, the overwhelming sentiment of students is,"If it works for us, it will probably work with our students."

The participants of this action research are personally involved with investigating pedagogy with the purpose of convincing them that s ,me teaching methods are better than others. In this case, that the effect of using hands-on involvement to promote the learning of science concepts dealing with pendulums is more effective than just reading about these concepts.. The results of this action research provide the students with convincing evidence that the use of hands-on activities is better pedagogy than the use of reading when the goal is to promote student learning and retention.

Hopefully, by doing action research in the methods classes, preservice and inservice teachers are encouraged to use action research themselves as one way of measuring their effectiveness. This should be a valuable tool for improving their instructional success.

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A Celebration of Learning

Ronald J. Bonnstetter

A father and mother approached me at the conclusion of one of our Celebrations of Learning with the following comments. "We just wanted to thank you for all your help in preparing our son to be a great teacher. Today was the first time in over 10 years of paying college tuition for our three children, that we have seen a real result or outcome. We can not believe how much growth our son was able to show, how many skills he now possesses and how clearly he stated his future goals."

These parents had just attended a ninety minute exit presentation to an audience that is many times composed of the instructor, other class mates, family members, significant others (spouse and/or friends), the student's cooperating teacher, and others as invited by the student. This last category has included professors (from both Arts and Science and Teachers College), and present, part-time employers of the presenter. In addition, open invitations are sent to incoming methods students and the cooperating teacher that the methods student will have the following semester during his or her student teaching.

An Overview

In preparation for this presentation, students have taken at least one methods course, a science curriculum class, and had at least two separate semester-long practicums. All of this is synthesized as the students construct portfolios that are revised throughout their careers. The portfolio contains at least four general categories and serves as the overlying structure for the final presentation: (a) a discussion of the teachers' rationale for teaching, (b) samples of products, (c) evidence of growth, and (d) a clear plan for future growth and development.

The Presentation

The actual presentation takes place during finals week, although large classes have used part of the previous week as well. A sign up schedule with all possible open dates and times is posted soon after mid-term and is full within a few hours. Because of scheduling concerns, evening slots are also made available. This many times is the only way to get cooperating teachers free to attend.

At least one week before the presentation, each student must submit a complete lesson plan for the presentation and a guest list. The presentation must employ the skills of the pre-service teacher and be based on sound educational research theory. Many of the presentation plans have been built around the learning cycle and use such strategies as cooperative groups, activities, computer

assisted instruction, as well as large group presentation skills. The key objectives for this time is to provide an overview of all four components of their portfolio while demonstrating appropriate teacher behaviors. Students have also shown segments of pre-post video tapes, examples of products using multimedia including hypercard stacks, quick-time clips, scanned student products.

Setting the Stage

From the very beginning of the semester, students are working on their portfolio. Table 1 is a brief project description that is given to these pre-service teachers as part of their first methods course syllabus.

Table 1
The Portfolio: On the Road to the Celebration of Learning

A portfolio is a systematic, well organized collection of evidence used to monitor the growth of a student's knowledge, process skills, and attitudes (Bonnstetter, 1992). Your portfolio will contain:

1. A well thought out and research supported *Rationale for Teaching* that describes your present vision and beliefs of teaching and learning.
2. *Products from the Semester* such as lesson plans, bulletin boards, exams, student projects, student evaluations, video tapes showing you working with large groups, small groups, and with individuals. Each of the tapes should be coded for teacher behaviors and critiqued in writing.
3. *Evidence of Growth* during the semester and/or career make up the third criteria. Examples include pre-post video tapes, revised products showing various stages of understanding including lesson plans, assessment instruments, student and teacher assessments and/or journal entries capturing different stages of understanding.
4. A *Plan for Future Growth* represents the final portfolio section. This establishes a path or set of goals for continued professional development.

Your portfolio is an organized and selective collection of evidence that documents what you know and what you know how to do in the teaching of science. Each section should consist of documents and/or products which are authentic evidence of your understandings or abilities as well as evidence of growth.

Your portfolio must be developed over time, therefore it will be a *dynamic form* of assessment that will be drafted, revised, and updated constantly. In other words, be prepared to add, replace, delete, and reorganize both your goals and evidence as you move through the remainder of your teacher preparation program.

Your portfolio is *rationale-based*. It is important for someone reviewing your portfolio to clearly see your vision of teaching science and that you are able to defend this vision with a sound research-supported base of knowledge. In addition to your rationale for teaching section, a statement of your three or four most important goals in each of the remaining sections will help introduce and focus the reader to see the connection between your goals and the evidence supplied.

Your portfolio is *selective*. From all the possible documentation at your disposal, you must choose those items that best demonstrate what you have accomplished or how you are moving to accomplish a particular goal. This is yet another good example of where the "right" choices confirm the "less is more" statement.

Your portfolio is *reflective*. It is extremely important for you to prepare short captions that either precede individual pieces of evidence or are attached in some manner to explain to the reader why this evidence has been included and what it shows about your understanding of teaching or your teaching abilities. This process will transform "stuff" into meaningful evidence that portrays you as an emerging teacher.

Your portfolio is *collaborative*. While you have the ultimate responsibility for developing a portfolio that documents your professional growth and development, you need to remember that teacher preparation is not a competition. You should consult colleagues for advice and feedback as you collect and select evidence and make decisions concerning presentation format. With the growing role of technology, the use of hypercard stacks and quick-time clips should be considered.

Your portfolio might include:

1. An introduction containing your rationale for teaching but starting with three or four overall goals statements and the advanced organizer for the reviewer about your document. The "rationale for teaching" document itself will take considerable time as you first draft thoughts and then boil them down to a concise five or six page statement. The rationale should provide insights into, for example, your understanding concerning: (a) why you will teach science, (b) what your goals for science students are, (c) how you will decide what content to provide, (d) what your curriculum will look like, (e) what you would like students to be doing in the classroom, (f) what you will be doing in the classroom, and (g) how you will provide evaluation of your program. Some of these sections will need research-base documentation to both explain and justify your vision.
2. A table of contents listing how you have organized your evidence sections and what they include.
3. All items you have selected to document your professional understanding and continued development.

4. Captions for individual documents that label, describe, and focus the reader toward your intended purpose for including this evidence. Captions should be brief, to the point, and clear; they should tell the reader what the document is, where it comes from, and what it suggests about you.

Even though the primary audience for the portfolio is you, the developing teacher, and your instructor, remember the other potential readers and their needs. These additional audiences might include cooperating teachers, school district recruiters, colleagues, and other university instructors. You may not be standing by for oral explanations, so design your portfolio to clearly speak for you and about you.

Before any trip can begin, you must know where you are going. During the first week of this class, course goals will be reviewed and revised based on specific needs identified by you and other classmates. These goals will serve as the initial criteria for which you should start the collection of evidence concerning your understanding of science teaching and your professional growth to that end.

Therefore, to begin building your portfolio:

1. Clearly state a set of goals for professional development. In other words, list what you hope to accomplish this semester and throughout the rest of your teacher preparation program.
2. Create a personal list of course requirements in a format that makes sense to you and contains specific check points in terms of degree of completion with calendar dates.
3. Create a collection of documentation you already have, you will have, or you could develop that will demonstrate that you have met or are working toward each of the specific goals for professional development you have established.

This portfolio project description was developed after a review of the literature and with assistance from English Teacher Educator, Dr. David Wilson, who shared his syllabus containing the English Methods "ELATEP Portfolio Project." In addition, ideas have been taken and adopted from Dr. Linda Vavrus's classroom handout, "Guidelines for Developing a Portfolio to Showcase Professional Growth and Learning."

The Developmental Phase

With the above guidelines for portfolio development in place, the methods sequence begins. Without going into another complete article describing the rather unique course itself, it may suffice to say that during the class, students are confronted with major paradigm shifts, the latest science and general education

reform literature, and numerous opportunities to practice and refine their teaching skills and understandings. Examples of other learning opportunities that occur before student teaching include:

Bulletin Board or Interactive Display

Each class member is responsible for providing our Science Education Center with one or more Bulletin Boards or interactive displays. Students as a group define the characteristics of a quality display, create their display, and use criteria to evaluate their own displays as well as the displays of others. Pictures are taken for possible portfolio inclusion.

Journal Article Review

Students use the following 3R outline to describe their response to and analysis of one article dealing with the teaching of science. The 3R response format is divided into three categories: Reaction, Relevance, and Responsibility. These categories closely resemble Bloom's Taxonomy of the domains of learning—the cognitive, the affective, and the psychomotor. The difference between the two nomenclatures is that the 3R Reaction scheme deals with the reaction of the affective domain first, rather than the cognitive. The rationale for the difference in placement is so the student can become aware of their affective response, and then deal with the cognitive merit of the learning regardless of the positive or negative affect associated with it. The 3R response format is also used by students as they make daily journal entries. When writing a 3R Reaction the following guidelines are followed:

1. Reaction (Affective Domain, To Feel). What was the reader's response (favorable, unfavorable, or mixed)? Give at least one example from the experience to support the point.
2. Relevance (Cognitive Domain, To Think). How pertinent is the event to the issue-at-hand (the conceptual framework of the event). The reader should be able to recognize and discuss how specific or important (meaningful) the event is to the course or issue and give at least one example from the reading to support the point.
3. Responsibility (Psychomotor Domain, To Do). How will the knowledge gained from the event be used in the everyday life of the reader? Give at least one example of possible application in your personal or professional life.

Pre-Course Teaching Experience

During the first week and again at the end of the semester students teach a ten minute lesson during class time. "You are to teach a topic of your choosing, based on what you know about teaching, and include a discussion within your lesson." A lesson plan is also to accompany each presentation. Both lessons are

videotaped and coded for teacher behaviors, interaction patterns and questioning strategy development.

Fourth and Fifth Grade Teaching Experience

Students prepare an activity, including a lesson plan for third through fifth grade gifted students. Each lesson is presented to our class and eight activities are revised for presentation in a nearby school. Only eight activities are presented to accommodate the school's eight period schedule and to allow manageable class sizes for these neophyte teachers. This activity requires a full day and occurs approximately six weeks into the semester.

Curriculum Project

First, students prepare a working definition of curriculum and then describe the components of their curriculum for a particular course of their choosing. The purpose of this activity is for students to become extremely familiar with a curriculum project, or a textbook series.

Professional Involvement

Each student is required to document a minimum of eight hours of professional involvement. Examples include Science Education monthly club meetings, and/or local, state, regional or national professional conventions. At least two of these hours should be volunteer work such as: science fair judging, Saturday science programs, Children's Museum, or assisting with an inservice presentation. Documentation should include a complete description of activities plus personal perceptions as to the value of the experience. All of this material may have a place in the portfolio.

Unit Lesson Plan

(This experience is to be tied to the practicum.) Students are to develop a topic into a unit of lessons that will run approximately 15 class days. The unit plan should include at least the following: (a) general goals, (b) objectives/outcomes for the unit, (c) major activities or components of the unit, (d) rationale for this topic, (e) materials needed (include cost and source), and (f) list of hazards and safety considerations.

In addition, daily lesson plans must be developed that include at least the following:

1. Specific lesson objectives/outcomes.
2. Materials needed for daily lesson.
3. A breakdown of components for each lesson with a time estimate.
4. Teacher behaviors predicted.
5. Student behaviors predicted.

6. Evaluation: (a) of student (included copies of assessments, portfolios, etc., and (b) of teacher.
7. Other items: (a) teacher questions that might be asked, (b) where the activity might lead (also extension activities), (c) how this might mesh with other science and non-science topics, and (d) space for teacher comments upon lesson completion.

Class Participation/Daily Assignments

There are numerous daily assignments. Much of the class time is spent in small group and large group discussions of reading assignments. Students are requested to prepare questions and/or comments over readings before these readings are discussed.

Inquiry Based Science Demonstration

Each class member prepares a three to five minute, teacher-centered demonstration, including a lesson plan handout for all class members. The presentation must model appropriate inquiry based teaching strategies. Portfolio entry should also be considered.

Weekly Journal Entries

This is an opportunity for students to "reflect" on their personal feelings and concerns toward teaching, as their philosophy emerges. A minimum of a half page entry per week is required and daily entries are required during special activities. Journal entries are electronically sent to the instructor at least once each week. All students are given a computer with modem at the beginning of the methods course and if necessary, they may keep the unit until the fall following graduation. The student computer loan program is composed of old IBM model XT's which have been donated by local businesses and other University departments as updated equipment is purchased.

Practicum Experiences

Each student will have had two practicum experiences at the completion of his or her methods and curriculum sequence. The first will entail a minimum of 40 hours of volunteer teaching in an informal setting. The second experience will require at least two periods everyday for 10 weeks. A list of recommended experiences for the formal practicum include:

1. Learn all students' names within the first two days.
2. Write and share observations of class sessions and particular students in assigned classes.
3. Assist with: taking roll, reading bulletins, handing out papers, and setting up and breaking down laboratory experiments.

4. Grade student papers.
5. Be familiar with school policies and procedures.
6. Create a bulletin board and/or window display.
7. Be involved with students in one-on-one and small group settings.
8. Observe one student over the semester and regularly log records on behaviors, interactions, class performance, physical changes, emotional reactions, and special needs.
9. Make explicit lesson plans based on student needs.
10. Teach as many lessons or portions of lessons as possible.
11. Plan and teach at least one topic area or complete unit as described in more detail in the major activity session.
12. Take time to reflect on experiences as a "Teacher Assistant."
13. Experience Team Teaching, not just turn teaching.
14. Demonstrate the use of checks for understanding.
15. Follow one student for as much of an entire school day and document and react to your findings.
16. Send reflections and reactions electronically to the university instructor, and other classmates when appropriate, at least once each week.
17. Administer an instrument to assess student perceptions concerning your interactions and teaching.

The Assessment Process

The cry nation-wide concerning portfolios and presentations is focused on "how do we assess them." The first step is to rethink our traditional view of grading and assessing. Once this has been accomplished and an understanding of summative and formative assessment developed, we will look back and wonder how we ever justified our antiquated letter and grade point approaches. But as an intermediate step, the following generic grade rubric may serve as a guide. Each semester this rubric is redefined by the class to best serve their developmental needs (see Table 2).

You also may notice that the rubric applies only to the course outcomes as a summative assessment. The portfolio has no assessment rubric and is handled as a formative course component.

Summary

Many of the students upon first examination of the course syllabus and goals immediately understand why the final is called a *Celebration of Learning*. As one student recently said, "Anyone who lives through this deserves to have a celebration." But just as the course syllabus ends with the following statement, we as educators of educators must also remember, that "The love of learning is caught, not taught." Portfolios provide the best option yet for each of us to catch a life-long love of learning. What about scheduling yourself for a portfolio presentation along with your students next semester?

Table 2
Science Education Grade Rubric

A—In addition to carefully completing all course goals and fully participating in all discussions and field experiences, an "A" in the methods block indicates that a student is extremely well-qualified in terms of teaching skills and possesses the ability to be outstanding during student teaching. This student displays quality planning, interacts well with students, shows command of subject matter and has ability to discuss a number of issues in science education. This student shows creative flair as well as a strong commitment to education. This individual is well on the way to becoming a formal operational teacher. Furthermore, all of the above criteria have been systematically documented and presented in his or her portfolio and during the Celebration of Learning.

B, B+—In addition to completing all assignments and participating in all field experiences, a "B or B+" indicates that this student possesses ability to plan, interact and deal with issues in science education. This individual understands the subject matter and can implement effective lessons. Both the portfolio and the Celebration of Learning indicate areas of need that the student has identified. This student has established a plan of action to meet the needs.

C+—This person possesses the basic competencies deemed necessary for science teaching. It is assumed that all course goals have been completed. This student may be quite successful in some areas and not so successful in others. A "C+" student may need special attention during student teaching to insure success and certification. The portfolio and the celebration of learning presentation should indicate areas of need but the student may not have developed a well thought out plan of action for further professional development.

C—A "C" grade indicates that the student is unsuccessful with the basic competencies even though this individual can direct a classroom given support and directions. This student may have achieved many of the course goals, but does not possess the basic competencies necessary to student teach. The portfolio and the Celebration of Learning presentation will show areas of accomplishment and how these skills will be redirected toward another career choice or how the student will back up and correct these deficiencies before being allowed to continue into student teaching.

D, F—Complete failure early in the term will signal a grade of "D or F." This individual will be counseled to drop the class and redirect their professional goals based on individual strengths.

This Rubric was originally created by Dr. John E. Penick and has been modified to serve as a sample for each new class to rework.

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BEHIND THE METHODS CLASS DOOR

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